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RADARC HF Ionospheric Prediction Program for OTH Radar

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A model for predicting the performance of an over-the-horizon high frequency (HF) radar is described. The program can also be used for management of an existing radar or for HF broadcasting assessment. When the radar parameters, such as power, antenna, and frequency are given the program predicts the signal-to-noise, ground clutter-to-noise, ionospheric spread Doppler clutter-to-noise, and received power as a function of range from the radar site.

The report is intended to provide the reader with a general description of the prediction model and to show those mathematics and procedures which are upgraded from NRL Report 2226. The procedures should provide the OTH radar engineers with information to execute the program for studies or evaluation of existing or planned radars.

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PART I

Theory and mathematics of RADARC

RADARC

HF IONOSPHERIC PREDICTION PROGRAM

for OTH RADAR

1.) Introduction

The OTH radar prediction model was developed by the Naval Research Laboratory (NRL) by contract to the Institute for Telecommunication Sciences (ITS) and Lucas Consulting. The program is designed for use as a tool in predicting or analyzing existing system performance for OTH radar facilities that use the HF (3-30 MHz) portion of the electromagnetic spectrum and the ionosphere as a propagation medium. The prediction program can be used in the design and siting of an HF radar installation as well as in the frequency and scan management of an operational site. This, however, does not limit the usefulness of program RADARC to radar applications alone. Organizations interested in HF broadcasting and communication will find that this prediction program can be used to evaluate many of the pertinent propagation problems affecting the reliability of the particular HF facilities. Some of the more common needed parameters in HF radar, broadcasting and communication operations are the expected limits for the take-off and arrival angles, height of reflection, area coverage and signal-to-noise ratio associated with given frequencies and times. Program RADARC predicts the above parameters among others and enables the user to ascertain revisions necessary in frequency complements, antenna selection, power requirement and/ or site selection in order to maintain optimum HF system performance.

This documentation is presented to assist the users of program RADARC to understand its general flow and to explain the essential calculations in the procedures involved. A continuous effort is being made to update the model and the procedures employed; thus all portions of the program are subject to revision.

The model used in the program RADARC for predicting the expected performance of ionospheric radar systems is the result of the philosophy and work of many investigators and no attempt will be made to credit all of the sources used. This documentation is intended to be a description of a computer program for users and not a monograph on HF ionospheric propagation.

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2.) Background

This section is intended to provide the reader with a general background used in the basic philosophy and development of the program RADARC.

Numerous organizations both governmental and private have been employing high frequencies to communicate between remote long distance point-to-point stations. It was recognized early that these types of communication systems were subject to marked variations in performance and it was hypothesized that most of these variations were directly related to changes occurring in the ionosphere. Considerable effort was made in the U.S. as well as other countries to develop research teams for the purpose of investigating ionospheric parameters and determining their effect on the nature of radio waves and the associated reliability of HF circuits. The investigators soon realized that effective operation of long distance HF systems increased in proportion to their ability to predict variations in the ionosphere because it allowed them to select optimum frequencies, antenna systems, and other circuit parameters that would capitalize on these variations. With the encouragement provided by these findings it was decided that a great deal more raw ionospheric data was necessary in order to develop models that could be used to adequately anticipate ionospheric conditions affecting HF propagation. Worldwide vertical incidence ionosondes were established and now measure values of f_oE, f_oFl, f_oF2, etc. as described in a later section. Worldwide noise measurement records were started and steps were taken to record observed variations in signal amplitudes over various HF paths. The results of this research established that ionized regions ranging from approximately 80 to 600 Km above the earth's surface provide the medium of transmission for electromagnetic energy in the HF spectrum (3-30 MHz) and that most variations in HF system performance are directly related to changes in these ionized regions, which in turn are affected in a complex manner by solar activity, seasonal, and diurnal variations as well as latitude and longitude.

The Radio Propagation Unit of the U. S. Army Signal Corps provided a great deal of information and guidance on the phenomena of propagation with HF in 1945 by issuing Technical Report No. 6[1]. By 1948 a treatise on ionospheric radio propagation was published by the Central Radio Propagation Laboratory of the National Bureau of Standards[2]. This document outlined the "state-of-the-art" of predicting expected maximum usable frequencies (MUF), depicted practical problems of ionospheric absorption and covered in detail acceptable methods of determining the MUF for any path at any time, and took into account the various possible modes of propagation by applying principles which were found to work in practice. The model used to make the MUF

predictions employed the "two control point" method and assumed the ionosphere to be concentric with reflection occurring only from the regular E- and F2-layers.

In 1950 Laitinen and Haydon[3] of the U. S. Army Signal Radio Propagation Agency furthered the science of predicting HF system performance by developing empirical ionospheric absorption equations and combining this with the theoretical ground loss, free space loss, and antenna power gain so that expected field strengths could be anticipated for radio signals reflecting from the E- and F-regions considering the effects of solar activity, and seasonal and diurnal extremes. The accumulative techniques and methods presented in the above-mentioned literature and many other studies were then combined to establish effective manual methods for predicting the expected performance of HF communication systems; however, these methods were laborious and time-consuming even if only estimates for the MUF and FOT (.85 MUF) were needed. To alleviate this problem, electronic computer routines were developed by such organizations as Stanford Research Institute[4] and the Central Radio Propagation Laboratory[5], all of which were based upon the established manual prediction methods. The latter program gave the first computerized technique that incorporated the numerical coefficient representation of the ionospheric characteristics. However, only the expected MUF and FOT were predicted. In 1962 a report was issued outlining a computer routine that used the most recent improvements in the theory of performance predictions, combining the more predictable ionospheric characteristics with circuit parameters to calculate expected HF system performance; MUF-FOT, system loss, reliability, etc.(Lucas)[6]

By 1960, it was recognized that high frequency radar systems could detect targets at considerable distances and consideration was given to the idea of applying the already developed computer programs used to predict the ionospheric effect on HF communication to the HF radar system. At the outset simple revisions were made to the HF prediction program including doubling the ionospheric losses associated with a given point-to-point path.

The predicted signal-to-noise ratios obtained by these modifications were compared with actual backscatter amplitudes and the results were encouraging. However, there were obvious deficiencies in the model that appeared immediately. To list a few:

1. Mirror reflection from the E- and F2-layers was not satisfactory.
2. The F1-layer was not included as a separate layer.
3. The sporadic E-layer was not included.
4. The take-off angle was not dependent on frequency.
5. Predicted losses were in error when transmission by the E-layer

was nearly specular.

It was possible to revise the prediction model to at least predict all of the above deficiencies. The development of the parabolic distribution of electron density model laid down in ITSA-1[16] was a first step. In this model the electron density profile along the path was assumed to be adequately represented by two parabolic layers, i.e, E and F2. The height of maximum ionization, semi-thickness, and electron density were derived from locations near the points of actual reflection along the path instead of the classical "two-control-point" method previously used in the calculation of the upper limit of frequencies and transmission loss.

The program RADARC is a direct descendent of the ITSA-1 model and does consider the E_s, E, F1, and F2 reflecting regions in the calculation of expected system performance for HF OTH RADAR[7]. The mathematics and method of generating the virtual height profile from the three parabolas is that of IONCAP[9]. Other modifications such as the revision to transmission loss at lower layers, obscuration by the E_s -layer, etc. will be discussed in detail in later portions of this report.

3.) General description of the radar model

The NRL HF OTH model is based upon the large volume of ionospheric data compiled over the years by the Institute of Telecommunication Sciences and is in the evolutionary line of the methods and computer models used in the analysis of communication systems. However, the emphasis in the NRL OTH model is on the description of the ionosphere along a great circle covered by the transmitted signal rather than the description of the electromagnetic environment at a single point as is the purpose of many other models.

The prediction model RADARC is an upgrade of RADARB as described by Headrick, Thomason, et al[7]. The mathematics of the geometry and the numerical evaluation of the coefficients associated with the ionospheric parameters are not included in this report as they are thoroughly covered in the above report. The ionosphere representation and development are those of IONCAP[9] and will be explained in detail in later sections. The program is no longer just a 'two control point' prediction routine, but will allow up to ten control areas sampled any reasonable arbitrary evenly spaced distance. It will allow calculations of from 1-hop to 4-hops of propagation by the E_s, E, F1, F2, or mixed modes using take-off angles from 0 to 45 degrees to sample the coverage area for the specified azimuth from the transmitter. The program will

calculate the signal-to-noise, earth clutter-to-noise, and the ionospheric spread Doppler clutter as described by Elkins[38,39] The program is very versatile with a plain language input file and highly documented output files, as will be shown in later sections on the input necessary to execute the program and the expected output.

Those readers not interested in the some of the mathematical and physical development of the program should go to part II. The prediction mathematics, data and calculations are summarized in the following sections. The first sections describe the development of the predicted ionosphere (h'F trace). The next sections describe the prediction and development of the transmission loss associated with the predicted virtual ionogram and the later sections describe the methods of predicting the coverage of the radar using the radar equation and the predicted noise environment.

The sections that immediatley follow will take you through the prediction routine RADARC, the data used to develop the ionospheric representation, the mathematics used in the virtual height vs frequency trace development, and the prediction of the transmission losses. These sections are from unpublished works of John L. Lloyd, Donald L. Lucas, and George W. Haydon[9].

4.) Virtual height ionogram technique and data

The prediction technique is a ray-path model using only data available for all values of the solar cycle, all times of the day, all months of the year, and all geographic locations. The mathematics for describing the ionosphere in virtual height and frequency resembles those of IONCAP[9]. The model assumes the vertical distribution of electron density with height can be modelled using a parobolic distribution for each layer. These parabolas are described by using the predicted critical frequency as the value at the nose and the predicted semi-thickness as its width. The height of the parabola is assumed to be at the predicted height of maximum. These parobolas are then overlaid upon each other in true height to form a true height profile of electron density (figure 1). The corresponding virtual height is found by integrating through this true height profile (figure 2). The virtual height profile thus generated is now used for all ray-path determination and calculation of angles of radiation. Figure 2 should be inspected carefully as this is the most difficult part of the prediction routine and the most lengthy to explain. Most other calculations depend to some extent on this ionospheric description. The following sections explain the data and method used to generate the predicted ionosphere.

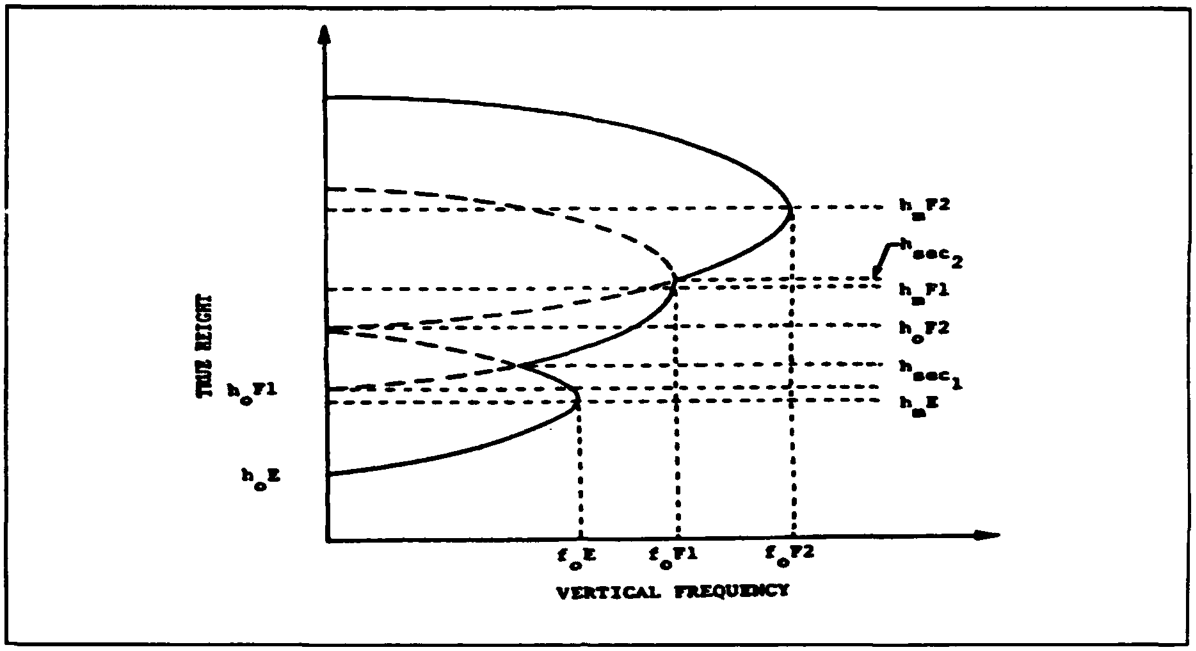

Figure 1 True Height profile using three overlapping parabolas.

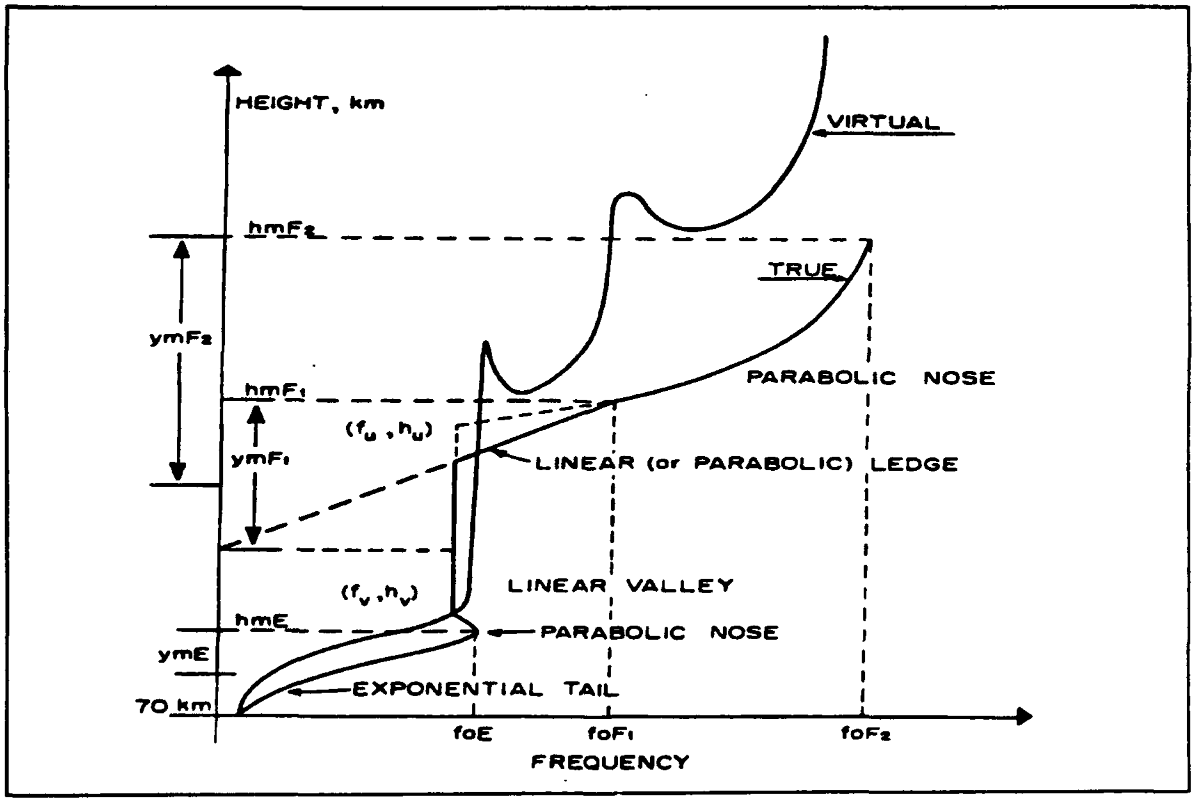

Figure 2 True height profile and virtual heights

Some discussion will be given about each contributing layer as the mathematics

are explained to help in understanding what is taking place in the ionospheric model development.

5.) Generating a virtual height profile

The ionosphere exhibits considerable systematic variability. If the minute-to-minute and the day-to-day variations within the month are averaged the remaining temporal variations (ie; diurnal, seasonal, and solar become fairly well behaved and predictable.

It is the purpose of this section to discuss parameters available to describe this quiet ionosphere and to review the available measurements and associated predictions for each region of the ionosphere.

Available ionospheric parameters, the use of these parameters to predict electron density profiles, and the use of the profiles to predict the geometry and losses associated with skywave propagation will be discussed in the sections to follow.

5.1) The D-region

Information on electron densities in the lower ionosphere (50-90 Km) is very inadequate for use in a prediction model such as this, primarily as a result of limited observation directed toward prediction use. The technical problems of observations are formidable, and the interpretation of measurements extremely difficult.

No D-region paramenters are directly included in the prediction model described in this report. The effect of the D-region is accounted for in two ways. First, the electron density distribution is extrapolated from the E-region using an exponential decrease to the height of 70 Km (Figure 2). Second, the effect of absorption is included in the loss equation.

5.2) The E-Region

A large volume of vertical-incidence ionosonde data has been collected over about three solar cycles, and many features of the E-region are therefore well known. The minimum virtual height of the E-region and the variation of maximum electron density within this region as a function of time and geographic location are readily obtained from the ionograms. The phenomenology of sporadic-E has been investigated, but classification of sporadic-E types remains unresolved. The effects of different types of sporadic-E on oblique-incidence radio propagation are not established; as a result, the compilation of meaningful statistics to form the basis of predictions

is difficult.

The E-region characteristics that have been systematically scaled from the vertical-incidence ionosonde records include:

f_oE The critical frequency of the ordinary component of the E layer; i.e., that frequency at which the signal from the ionosonde just penetrates the E-layer.

$h'E$ The minimum virtual height of the E-layer, measured at the point where the trace becomes horizontal.

f_oE_s The highest observed frequency of the ordinary component of sporadic E (E_s).

$h'E_s$ The minimum virtual height of the sporadic-E layer, measured at the point where the trace becomes horizontal.

f_bE_s The blanketing frequency; i.e, the lowest ordinary wave frequency at which the Es layer begins to become transparent, usually determined from the minimum frequency at which ordinary wave reflections of the first order are observed from a higher layer.

The regular E-layer is predicted using three parameters: the monthly median value of critical frequency (f_oE), height of maximum ionization of the layer (h_mE), and ratio of h_mE to semi-thickness (y_mE). Worldwide numerical coefficients of monthly median f_oE are available for computer applications in terms of geographic latitude, longitude, and universal time. The coefficients (Leftin)[10] were derived from measurements taken during a year of minimum and a year of maximum solar activity. A linear interpolation is used to obtain estimates at other phases of the solar cycle. An examination of monthly median h'E observations indicates negligible seasonal or geographic variations in the minimum virtual height of E-region ionization. A typical value is 110 km. The D-region ionization is included as an exponential decrease below the E-layer; an h_mE of 110 km and an h_mE/y_mE ratio of 5.5 are assumed; i.e., $y_mE = 20$ km.

Numerical coefficients are also available for each month representing the median and decile values of f_oEs (or f_oE) in terms of a modified magnetic-dip angle, longitude, and universal time (Leftin)[11]. These numerical maps are from data taken during periods of solar activity minimum

and solar activity maximum. Linear interpolation is used for other levels of solar activity. Unless other information is available, the virtual height of the sporadic-E layer is assumed to be 110 km.

5.3) The F-Region

The vertical-incidence ionosonde network, with its long series of measurements over much of the world, provides the basis for F-region predictions (Martyn)[12]. The following parameters have been systematically scaled from the vertical ionosonde records (Piggott and Rawer)[13], although some stations do not report all of them:

f_oF2 The critical frequency of the ordinary component of the F2-layer; i.e., that frequency at which the signal from the ionosonde just penetrates the F2-layer.

M(3000)F2 The factor for converting vertical-incidence critical frequencies to oblique incidence for a distance of 3000 km via the F2-layer.

f_oF1 The critical frequency of the ordinary component of the F1-layer; i.e., that frequency at which the signal from the ionosonde just penetrates the F1 layer.

h'F The minimum virtual height of the F-layer; i.e., the minimum virtual height of the night F-layer and the day F1-layer. It is measured at the point where the F trace becomes horizontal. (In earlier years the minimum virtual height of the night F-layer was often combined with that of the day F2-layer, the combined tabulation being designated h'F2. In these cases, the minimum virtual height of the F1-layer, h'F1, was tabulated separately.)

h'F2 The minimum virtual height of the F2 layer, measured at the point where the F2 trace becomes horizontal.

h_pF2 The virtual height of the F2 layer corresponding to a frequency f, where f=.834 f_oF2. This is based on the assumption of a parabolic ionization distribution, which is usually considered justified as an approximation to the height of maximum ionization of the F2 layer.

The F2 layer is described by three parameters: monthly median value of critical frequency (f_oF2), height of maximum ionization (h_mF2), and a ratio of h_mF2 to semithickness y_mF2. Monthly median values of f_oF2 and the M(3000)F2 for two solar activity levels are available as numerical coefficients in terms of a modified magnetic-dip angle, longitude, and universal time (CCIR)[7]. The solar activity dependence is accounted for by linear interpolation. The height of maximum ionization is determined by first estimating the virtual height at 0.834 f_oF2; i.e., h_mF2. The geometric formula used is:

$$h_pF2 = -176 + 1490/M(3000)F2 \tag{1}$$

The expected accuracy of the formula is within 6 percent (Shimazaki)[14]. The form of equation (1) is governed by the geometry of a wave propagating in a spherically symmetric earth-ionosphere medium. The 176 is the bulge of the earth for a 3000 km path. The 1490 is an approximation of the quantity

$$S = .417\, P'k \tag{1a}$$

where P' is the group path (slant range) and k is the usual secant correction factor. The basic equations used are

$$f_{ot} = f_v k \sec\phi \tag{1b}$$

$$f_{ob} = [M(3000)F2][f_oF2] \tag{1c}$$

$$\sec\phi = 1/2\, P'/(h_mF2 + 176). \tag{1d}$$

Let f_v = 0.834 f_oF2. Equation (1a) is the secant "corrected" law; equation (lb) is the definition of the 'M' factor; and equation (1c) is a trigonometric identity . (Snell's law, Martyn's

theorem, and Breit and Tuve's theorem are all implicit here. Any correction to equation (1) should be in the factor 1490. The height of maximum ionization is then found by removing the retardation caused by lower region ionization; i.e.,

$$h_mF2 = h_pF2\text{-}R. \tag{2}$$

The formulas for 'R' (Budden)[14] depend upon the electron density profile assumed for the lower layers. For example, D-E ionization as a parabolic layer with an exponential decrease at the lower heights, the E-F valley as a linear profile, and the F1, when present, is assumed to be a linear or parabolic ledge. The ratio (h_mF2/y_mF2) is available as a function of the sun's zenith angle (positive for afternoon, negative for morning), geomagnetic latitude, and solar activity, as shown in figure 3 (Lucas and Haydon)[16]. These contour were developed from 75th meridian data of computerized true height reductions of ionospheric recordings (Wright)[41].

The F1-layer is not always present. When present, it is described by three parameters--the critical frequency (f_oFl), the height of maximum ionization (h_mFl), and the semithickness (y_mFl). Numerical maps of f_oFl are available (Rosich and Jones)[17]. These maps provide f_oFl as a function of solar zenith angle, are continuous throughout the year, and are linear with solar activity. The F1-layer fades out at a maximum value of the sun's zenith angle. The height of maximum ionization (h_mFl) appears to depend upon the zenith angle of the sun and is estimated in this report as follows:

$$h_mFl = 165 + .6428\chi \tag{3}$$

h_mFl - height of maximum ionization of the F1 layer in kilometers
χ - zenith angle of the sun in degrees.

The ratio of h_mFl to the semithickness of the F1-layer is assumed to be 4.0. The presence of the F1-layer is primarily a function of the sun's zenith angle, but also depends upon time of year, a modified magnetic-dip angle, and solar activity level. The values of h_mFl and y_mFl are adjusted so that the F1-layer smoothly merges into the other regions.

It must be noted that the values of h_mFl and y_mFl are tentative and require adjustment,

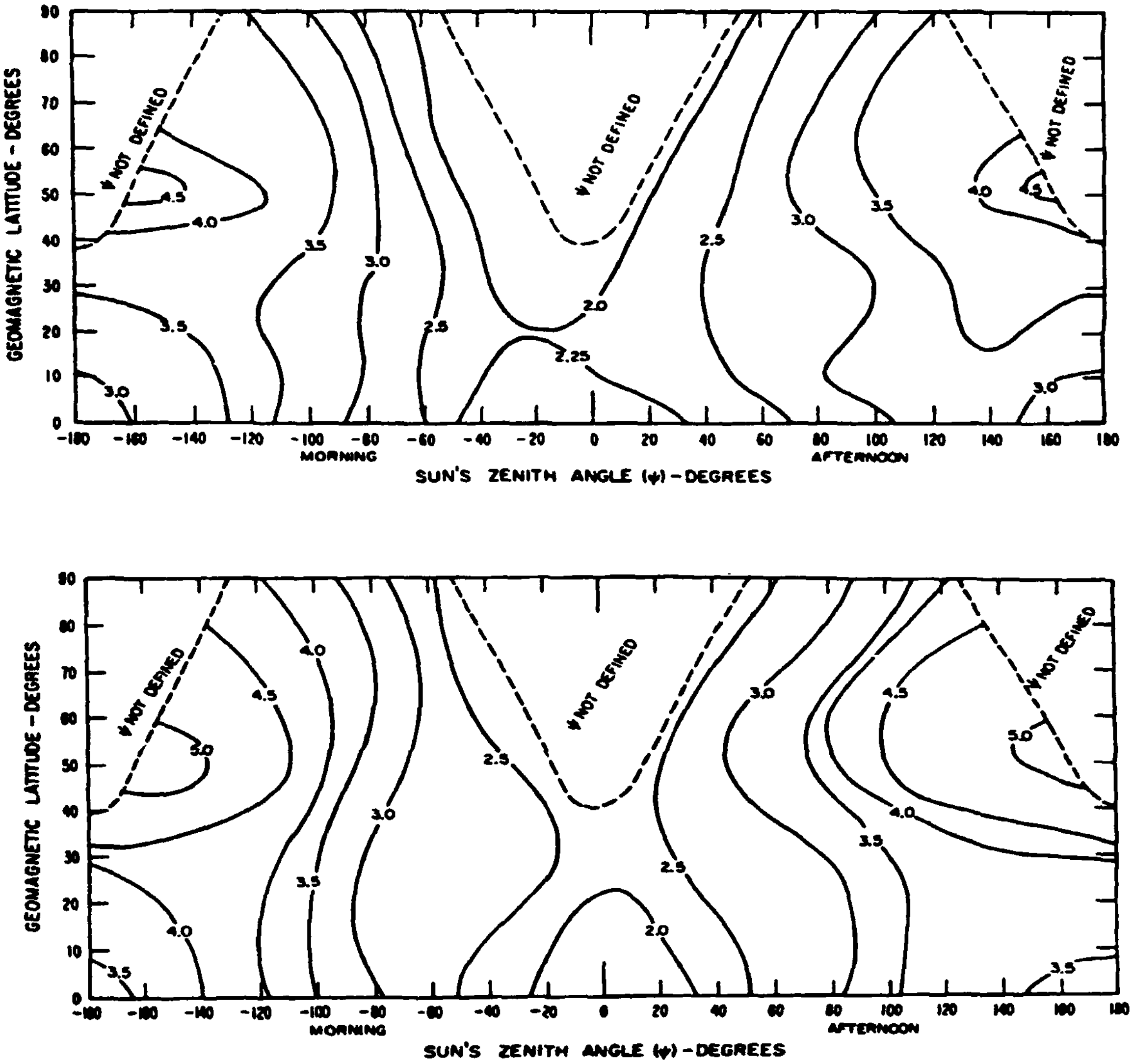

Figure 3 Contours of the ratio h_mF2/y_mF2- top high SSN bottom low SSN.

depending upon the ionization of the F2 layer in the development of an electron density profile.

The above ionospheric parameters are selected from those available with emphasis on obtaining consistent parameters for the generation of an adequate electron density profile for estimating the ray-path geometry of high-frequency skywave signals. Other ionospheric parameters which are available but which are not used include:

- Maps of f_oF2 with a nonlinear dependence on solar activity are not used because the maps of the associated parameter M(3000)F2 are

available only with a linear dependence on solar activity.

- Neither h'F,F2 nor h'F,F1 maps are used because the frequency at which the height applies is not measured and it is impossible to adjust for lower region retardation. Maps of f_oF2, M(3000)F2, and the ratio h_mF2/y_mF2 are from the same data base and are statistically and physically consistent.
- Maps of f_bEs are not used because values are available only for a low solar activity.

6.) Electron density profile model

Frequency versus virtual height traces of the ordinary wave as available on vertical incidence ionograms can be converted into electron density profiles by a standard reduction program. These profiles, including geographic, diurnal, seasonal, and solar cycle variations, are generated between heights of 70 km and the height of maximum of the F2 layer, h_mF2. The electron density is given by the relationship

$$N = 1.24 \times 10^{10} f_N^2 \tag{4}$$

N electrons per cubic meter

f_N plasma frequency MHz.

The profile is generated in four steps: D-E region, F2-layer, E-F2 valley, and an F1 ledge. This form of electron density profile evolved over the years. A fixed reflection height for the E- and F2-layers was used in the original computer program (Lucas and Haydon). Then parabolic layers for both the E and F2-layer were used (Lucas and Haydon)[16] and (Barghausen et al)[28]. The F1-layer was added and the profile was generated by taking the maximums of these intersecting parabolas (Haydon and Lucas)[18]. The resulting profile is then a computerized version of this manual method of analyzing measured ionograms (Ratcliffe)[19]. In all of these programs, the electron density is only implicit in the functional form of the equations used for virtual heights or ground distance. The method described here gives an explicit form for the profiles

(Figure 2).

6.1) D-E Region

The ionospheric parameters assumed available are the monthly median critical frequency of the E-layer (f_oE, MHz), height of maximum ionization of the layer (h_mE = 110 km), and ratio of h_mE to semithickness (h_mE/y_mE = 5.5).

The nose (figure 2) of the layer is parabolic $f_N(h)$ is the plasma frequency at a

(5)

$$f_N^2(h) = (f_oE)^2 \left[1.-(\frac{h_mE-h}{y_mE})^2\right]$$

height h. The ionization is assumed to decrease exponentially starting at the lower part of the E region ($h_{ex}= h_mE$ -.85 y_mE), with the constants chosen so the slope of the profile is continuous at this point. *(A discontinuous slope results in a cusp in the virtual-height ionogram derived from the profile.)* The equations are

(6)

$$f_n^2(h) = (f_oE)^2 F^2 \ \exp[\alpha(h-70.)]$$

$$\begin{aligned} \alpha &= 2(h_mE - h_{ex})/(.2775\ (y_mE)^2) \\ &= 6.121/y_mE \\ &= .3062\ ,\ for\ y_mE = 20 \end{aligned}$$

where

$$F^2 = [1.\ -\ (.85)^2]\exp[-\alpha(h_mE\ -.85y_mE-70.)]$$

This equation gives a value of f_N^2 at 70 km as $(f_oE)^2$ F^2. With h_mE as 110 km and y_m as 20 km, this profile yields a virtual height of 100 km at .04 $(f_oE)^2$ and of 110 km at 0.52 $(f_oE)_2$,corresponding roughly to typical measured values.

6.2) F2-Layer

The ionospheric parameters assumed available are the monthly median critical frequency of the F2 layer (f_oF2, MHz), height of maximum ionization (h_mF2, km), and the ratio of h_mF2 to semithickness of the layer (y_mF2).

(7)

$$f_N^2 = (f_oF2)^2\ [1.-(\frac{h_mF2-h}{y_mF2})^2]$$

6.3) E-F2 Transition Region

Only the total density in this region is modeled, not the shape. This is normally, but not necessarily, a valley. It is represented by a line from a frequency f_u at the F2 layer to a frequency f_v at the E layer:

(8)

$$f_N^2(h) = f_u^2 + (f_u^2 - f_v^2)[h - h_u)/(h_u - h_v)]$$

where

$$f_u = x_u\, foE$$

$$f_v = x_v\, foE$$

$$h_u = h_mF2-y_mF2\sqrt{(1.-(f_u\ /\ f_oF2)^2)}$$
$$h_v = h_mE + y_mE\sqrt{(1.-(f_v\ /\ f_oE)^2)}$$

Typical values for the constants x_u and x_v are .98 and .8516, respectively. If $x_u = x_v = 1$,

there is no valley.

6.4) F1-Layer

The F1-layer is considered to be a ledge from the F2-layer to the E-F valley (or possibly to the E-layer). If the F1 ledge exists, it is described by three parameters: the critical frequency (f_oFl, MHz), the height of maximum ionization (h_mFl, km), and the semithickness (y_mFl, km).

The F1 ledge may be either a linear or a parabolic layer. If the height of maximum ionization of the F1 ledge is less than the height of the F2-layer at the frequency of f_oFl, the parabolic layer shape is used. If the height of maximum ionization of the F1 ledge is greater than the height of the F2-layer, then the height of maximum ioni?ation of the Fl ledge is reduced to the F2-layer height. This procedure assures that a cusp in a virtual height trace occurs at the critical frequency of the F1 ledge. The slope, S1, of the linear layer shape using the F1 ledge parameters (f_oFl, h_mFl, y_mFl) is compared to the slope, S2, of the F2-layer at the F1 critical frequency. If the difference of the slopes is positive, the linear ledge is used; if negative, the parabolic layer shape is used.

This procedure assures that the F1 ledge will appear in a virtual height trace and that the F1 ledge will gradually disappear into the F2-layer as the difference of the slopes approaches zero. When this difference is small, the resulting ionogram will be L-shaped.

Also, the F1-layer, when parabolic, can dominate as f_oFl approaches f_oF2, as occasionally happens, especially in the Northern latitudes. The equations are:

(9)

$$h2 = h_mF2 - y_mF2\sqrt{(1 - (f_oF1 / f_oF2)^2}$$

and slopes

$$S2 = 2(f_oF2)^2 (h_mF2\text{-}h2)/(y_mF2)^2$$

$$S1 = (f_oF1)^2 / y_mF1$$

for a linear ledge (i.e., $h2 < h_m$Fl and $S2 < S1$)

$$f_N^2(h) = S1\ (h - h2 + y_m F1) \tag{10}$$

and for a parabolic ledge

$$f_N^2(h) = (f_o F1)^2 \tag{11}$$

$$[1 - ((h_m F1 - h/)y_m F1)^2]$$

Sample numerical maps of the variation of plasma frequency with height, geographic location, and local mean time developed for limited time periods (Jones and Stewart)[20] are not applicable to other time periods. The approximate electron density profile described above uses predictions of ionospheric parameters now available for all time periods and includes variations with latitude, longitude, local time, month, and solar activity. Both the profile and its slope are continuous except perhaps at the predicted critical frequencies (see Figure 2). Although the methods are primarily for use with predicted monthly median values, they are applicable to daily ionospheric parameters. The electron density profile (in tabular form) can be used in ray-tracing programs or to generate virtual-height ionograms, or in the propagation prediction programs.

7.) Virtual height ray path model

This section describes a simple computation method for obtaining all the single-hop ray paths through an ionosphere described by an electron density profile. It uses the classical relationships between the virtual-height ionograms and the oblique path. However, Martyn's equivalence theorem is used in a "corrected" form as described by Lloyd[8]. First, the ionogram is obtained using numerical integration techniques. Then reflectrices are obtained as a single table incorporating all ray-path information. Finally, the correction to Martyn's theorem and a table look up and interpolation procedure are used to find the ray sets which describe the propagation for a particular operating frequency.

7.1) Virtual height ionograms

Virtual heights for the ordinary trace are found from the electron density profile by numerically integrating the equation

$$h'(f_v) = h_o + \int_{h_o}^{h_r} \mu'(h,f_v)\, dh$$

(12)

where

$$\mu'(h,f_v) = [1 - f_N^2(h)/f_v^2]^{-1/2}$$

f_v selected vertical sounding frequency;
h_o lowest true height of the profile, i.e., 70 km;
h' virtual height of the profile;
h_r true height corresponding to f_v;
h true height of reflection;
μ' group index of refraction;
f_N plasma frequency.

The area is found using a Gaussian integration technique (see Figure 4). The effect of the cusp at h can be lessened by using a nonlinear transformation from the interval [h_o , h_r], to [1, 1]. The transformation and integration equations are:

(13)

$$h_j = (h_r - h_o)[1 - 2^{-m}(1 - X_j)^m]$$
$$\mu'_j = \mu'(h_j , f_m)(1 - X_j)^{m-1}$$

$$h' = h_o + (h_r - h_o)(m/2^N) \sum_{j=1}^{N} w_j\, \mu'_j$$

h_j = true height corresponding to (w_j , X_j);
X_j = Gaussian abscissa;
w_j = Gaussian weight;
N = number of Gaussian terms (at least 40) for electron density profiles

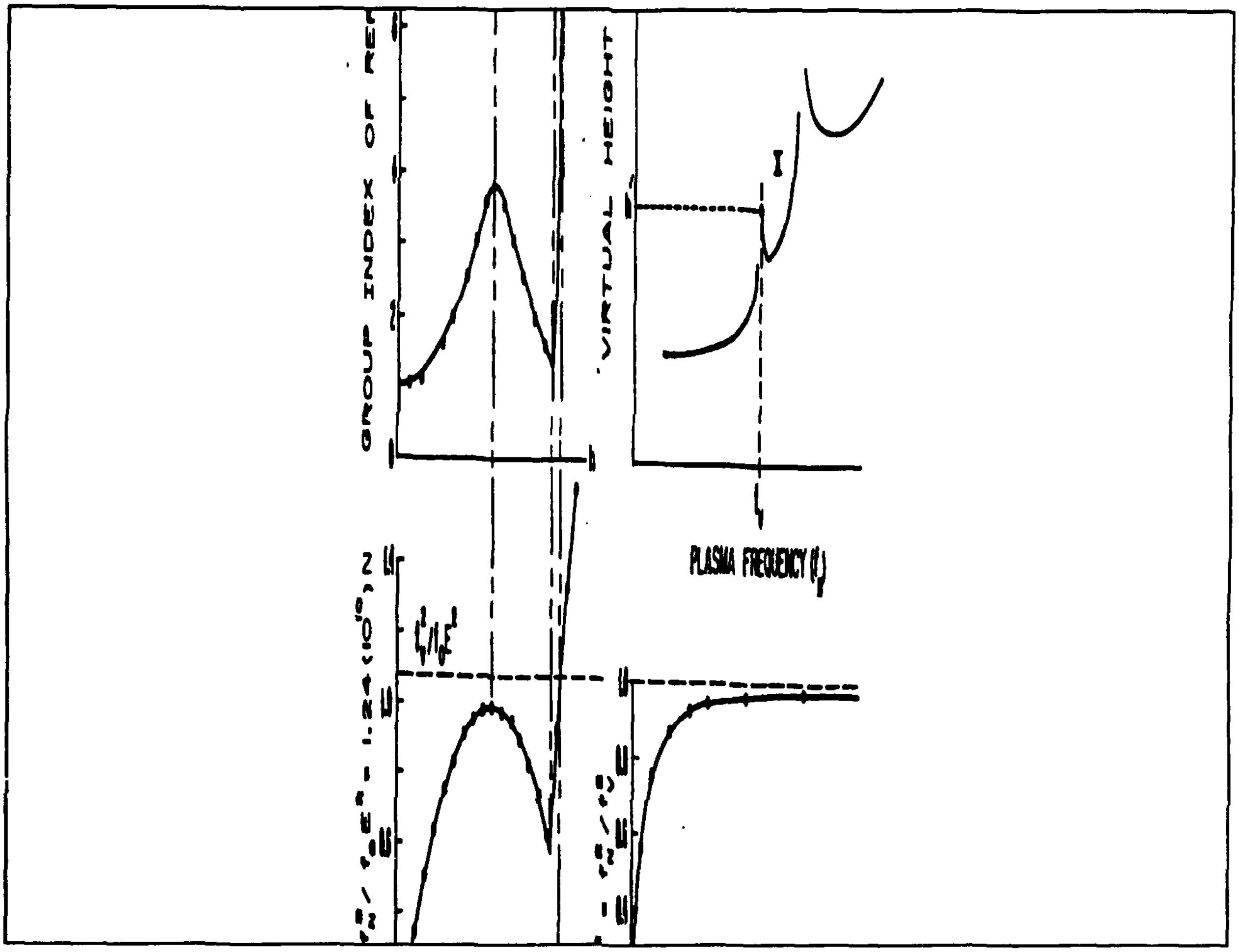

Figure 4 Gaussian integration

A forty-point Gaussian integration was found to be adequate when the electron density profile was sampled at true height intervals of 4 km and the vertical sounding frequencies were selected at intervals of 0.2 MHz.

The Gaussian method tends to smooth out the "kinks" in the resulting ionogram introduced by using a tabular form of the electron density profile. When $m=1$, it corresponds to the usual Gaussian formula for an arbitrary interval.

When the F1-layer is not present, a faster integration method is available. The D-E region values are taken from a table which was calculated by the Gaussian integration using $h_mE = 110$ and $y_mE = 20$. The F2 layer is calculated using model segments.

8.) Reflectrix model

Skywave radio propagation paths may be described by a set of parameters known as raysets (Croft)[21]. For most HF radar and communication applications, this consists of operating frequency, takeoff angle, virtual height of reflection, true height of reflection, and ground distance. The basic inputs are true and virtual heights as a function of vertical-incidence frequency.

The ray paths are calculated using the following simplifying assumptions:

1. Horizontal and azimuthal variations in the ionospheric electron density profiles are negligible for each hop (on a multihop path, different sample areas are used).
2. The magnetic field may be ignored.
3. The ionosphere is spherically symmetric to the earth.

With these simplifications, the equivalence between a given frequency on an oblique path (f_{ob}) and a vertical incidence frequency (f_v) with the same vertical height specified by Snell's law is

$$f_{ob} = f_v \sec\phi_t \tag{14}$$

where

ϕ_t is the angle between the apparent ray path and the normal to the earth at the true height of reflection.

By simple geometry, the virtual height of the oblique path is related to the takeoff angle Δ by (figure 5).

$$a\cos\Delta = (a + h'_{ob})\ \mathrm{Sin}\ \phi' \tag{15}$$

where

Δ = takeoff angle of the ray,
a = earth's radius,
h'_{ob} = virtual height of the oblique path,
ϕ' = is the angle between the virtual ray and the normal to the earth at h'_{ob}

Martyn's theorem for a plane ionosphere specified the ray path by the equality of the virtual

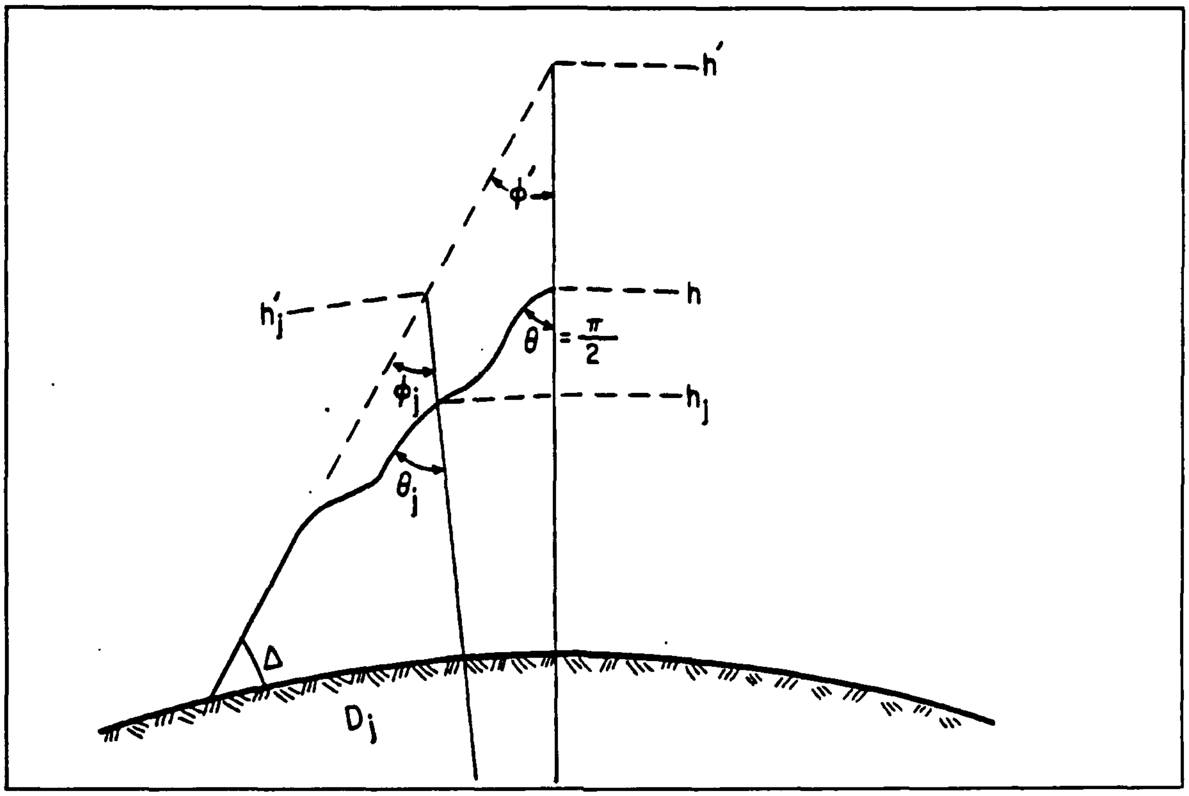

Figure 5 Oblique raypath geometry for three layers.

height of the oblique path, with the virtual height of the ionogram at the equivalent frequency f_v. For a curved ionosphere, this leads to a consistent error at higher frequencies for thicker layers. The Breit and Tuve theorem states that the time taken to transverse the actual path is the same as that which would be taken to transverse the equivalent path in free space. Both theorems are corrected in the following model by an empirically derived correction (Lloyd)[9] factor which depends only on the electron density profile and the curvature of the ionosphere:

$$h'_{ob} = h'_v + \left(\frac{f_{ob}^2 - f_v^2}{f_o F_2^2}\right)\left[h\left(\frac{h'_v - h}{a}\right) + 2(a+h)\left(\frac{h'_v - h}{a}\right)^2\right] \tag{16}$$

Note..h'_{ob} has changed definition.

where

f_oF2 is the F2 critical frequency,

h' is the virtual height corresponding to f_V,

h   is the true height of reflection

This correction has errors of less than one percent as compared with the distances calculated by a ray-trace program based on Haselgrove's equation method (Haselgrove)[22](Finney)[23]

Table I   Relationship between vertical data (Ionogram) and oblique data (Reflectrix)

Ionogram values

f_v-MHz	.91	1.82	2.72	2.83	2.95	3.06	3.17	3.29	3.40
h_t-Km	74.2	89.0	98.0	99.0	100.0	101.3	102.9	105.0	110.0
h'-Km	83.9	103.0	114.0	114.6	116.3	119.6	124.4	132.1	175.7
Angs. deg.	Reflectrix oblique frequencies - MHz								
0	6.04	10.99	15.68	16.26	16.82	17.36	17.87	18.33	18.53
5	5.25	9.75	14.06	14.59	15.11	15.61	16.09	16.53	16.80
10	4.01	7.03	11.17	11.60	12.04	12.46	12.88	13.27	13.57
20	2.47	4.84	7.18	7.47	7.76	8.05	8.34	8.62	8.88
30	1.77	3.49	5.21	5.42	5.64	5.85	6.07	6.28	6.48
40	1.40	2.77	4.14	4.32	4.49	4.66	4.83	5.00	5.17
50	1.18	2.35	3.51	3.66	3.81	3.95	4.10	4.24	4.39
60	1.05	2.09	3.13	3.26	3.39	3.52	3.64	3.77	3.91
90	.91	1.82	2.72	2.83	2.95	3.06	3.17	3.29	3.40

The model uses equations 14 and 15 to generate Table I. The first row is the vertical incidence frequency f_v in megahertz. The second row is the true height of reflection, h_t; the third row is the virtual height of reflection h' and the rows following are the equivalent oblique operating frequencies for ray paths with corresponding takeoff angles at the transmitter.

When the information such as that contained in Table I is plotted in constant frequency contours of virtual reflection height and distances as in Figure 6, the displayed contours are called reflectrices (Lejay and Lepechinsky)[24]. At each given operating frequency, the area coverage is found by interpolating in Table I for the desired ray paths. This procedure yields the

Table II Rayset for a single operating frequency.

RAYSET FOR FREQUENCY = 10.00 MHz

DISTANCE	ANGLE	VIRTUAL	TRUE	MODE	f_v
2240.69	0.00	99.81	86.03	E	1.64
2132.85	50	99.85	86.07	E	1.64
2031.62	1.00	100.03	86.19	E	1.65
1848.52	2.00	100.66	86.68	E	1.68
1689.82	3.00	101.70	87.46	E	1.73
1553.09	4.00	103.08	88.51	E	1.79
1431.40	5.00	104.33	89.49	E	1.87
1323.49	6.00	105.49	90.43	E	1.96
1147.44	8.00	108.15	92.59	E	2.18
1012.11	10.00	111.13	95.02	E	2.42
906.11	12.00	114.34	97.62	E	2.68
819.51	14.00	117.39	100.15	E	2.96
1024.54	16.93	181.35	109.96	E	3.40
1817.87	16.93	359.68	153.64	1	3.40
1213.47	18.00	234.01	158.34	1	3.73
1121.66	20.00	237:04	163.87	1	4.01
1194.88	22.00	280.89	174.09	1	4.31
1496.14	22.52	374.11	182.41	1	4.40
2184.89	22.52	595.08	210.45	2	4.40
1349.37	24.00	354.18	215.75	2	4.68
1209.20	26.00	340.38	221.60	2	4.96
1133.13	28.00	343.83	228.35	2	5.23
1094.45	30.00	358.10	236.32	2	5.50
1084.19	32.00	383.12	246.06	2	5.77
1127.25	34.00	432.03	259.43	2	5.05
1942.44	35.70	874.76	290.49	2	6.30

desired reflectrix for the given frequency in the form of a table of raysets as in table II. Calculations are not necessary at each frequency as all the desired information is contained in Table I. For two-hop modes, a table of reflectrix information (as in Table I) is generated for the second-hop sample area, and at the given operating frequency, a table of rayset information is generated as in Table II. The two-hop modes are found by matching the takeoff angle of the second hop with the arrival angle of the first hop. Note that there has been no mention of individual layers (E, F1, or F2) since the electron density profile was generated. The ionosphere is treated as a single region by the program, and all possible mode combinations are generated. In order to keep the traditional layer nomenclature, the ray paths are named according to where their equivalent vertical frequencies lie (e.g., below foE); thus the modes may be E-E, F2-F2, E-F2 according to the label of each hop. Since the sporadic-E modes are assumed to exist with some degree of probability with reflection at a constant height, the rayset information is the same

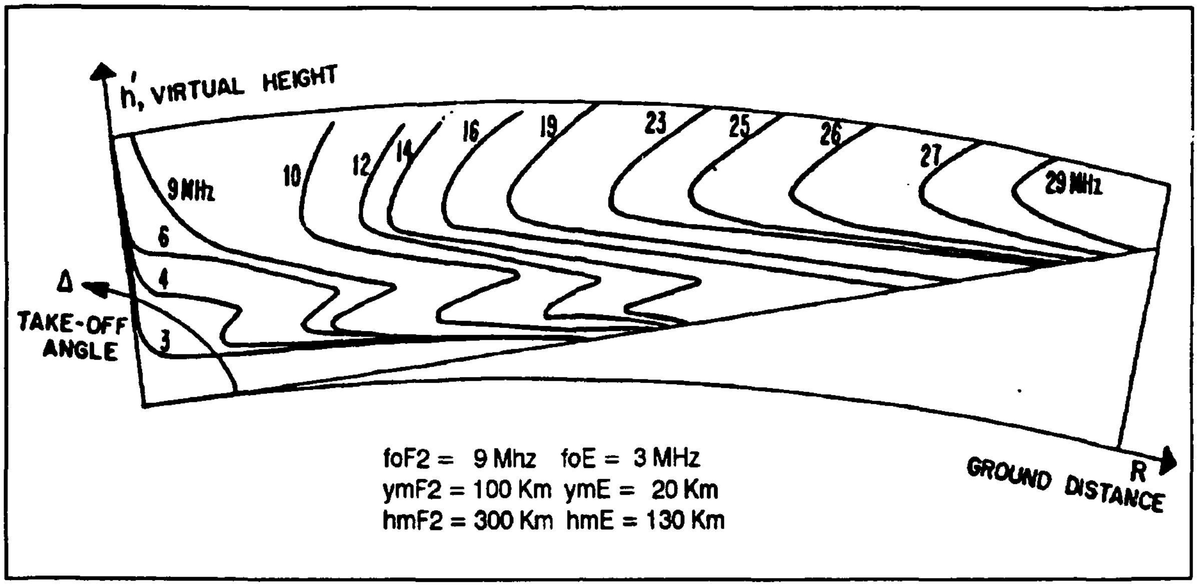

Figure 6 Reflectrix.

for each operating frequency and there is no need to generate the equivalent of Table I for the E_s mode.

Using the results of table II the ground distance can be obtained by interpolation for any vertical angle of take-off for a specified operating frequency ie; 10 MHz in the example. The on azimuth ionospheric coverage by this rayset is 819.51 to 2240.69 km.

9.) Ionospheric loss model

This section describes the equations and data used to calculate ionospheric losses associated with a mode of propagation. The model is intended to cover the frequency band from 3 to 30 MHz. All modes which result from a complete electron density profile are covered, as well as sporadic-E modes. Lower decile, median, and upper decile values of field strength, signal, or signal-to-noise ratio can be determined by the metho. . lescribed. The theoretical background and method of measurements are given in the N ial on Ionospheric Absorption Measurements (Rawer)[25]. The equations described below are intended to be used on a worldwide basis, and are limited by the available worldwide prediction data base.

The equations are based on the CCIR 252-2 loss equation[26] using a philosophy that modifications are made only when measured values demand a change. The CCIR loss equation was primarily derived from F2 low-angle modes with operating frequencies not greater than the FOT. For these conditions, there is no need to modify the equation. For E-layer low frequency modes which do not penetrate very deep, two modifications were necessary. A correction factor to account for less E-layer bending was added [equation (25)]. Since an arbitrary electron density profile can be used, the true height of reflection may be written into the D-layer absorbing region, resulting in lower absorption. This has been accounted for by modifying the collision frequency factor in the denominator [Equation (27)]. In addition to the D-region losses due to absorption, there may be losses at the area of reflection if the ionization of the region is insufficient to reflect all the radio energy. This loss increases as frequency increases, and starts to be significant as the frequency nears the MUF, and increases rapidly above the MUF. Since this loss is closely associated with the MUF, the day-to-day variation of the MUF within the month can be used to estimate the variation of these losses with frequency. The 10% and 90% values of the distribution are taken as 1.15 and .85 respectively in RADARC. This loss due to partial failure of ionospheric support is referred to as an "over-the-MUF" loss [Equation (29)]. Since the basic loss equations contain the average effect of deviative absorption, an additional loss is only added to the high-angle modes (including those F modes on the upper side of the E or F1 MUF [Equation (28)]. Sporadic-E mode losses are determined as are the regular E modes, but the deviative loss is zero and the over-the-MUF loss is what is usually termed reflection loss (Equation (30)].

The equations referred to provide monthly median losses when used with monthly median parameters of the ionosphere. In order to evaluate the performance of a communication system, the distribution of these losses within the month is needed. These distributions have been given as tables of transmission loss distributions (CCIR 252-2)[26] and are uniform for operating

Table III Excess system loss (dB) for high (N or S) latitude paths.

(Equinox - Paths > 2500 km)

	01-04 LMT			04-07 LMT		
G.M. Lat.Deg	Median	S_l	S_u	Median	S_l	S_u
0-40	9.0	4.0	9.0	9.0	4.0	2.6
40-45	9.3	4.1	10.0	9.3	4.1	8.5
45-50	9.6	4.2	11.0	9.6	4.2	9.4
50-55	9.9	4.4	12.1	9.9	4.3	10.3
55-60	10.4	4.5	13.2	11.0	4.6	10.6
60-65	12.9	5.7	15.5	14.2	5.9	10.8
65-70	12.7	5.7	14.3	14.6	6.6	10.6
20-25	10.8	4.6	13.1	11.9	5.3	9.8
75-80	10.0	4.8	11.0	10.2	4.6	9.0

frequency and for mode type. For geomagnetic latitudes below 40 degrees, these tables are for frequencies less than the FOT and are the variation of the losses about the CCIR 252-2 equation based on 83 circuit years of data (Laitinen and Haydon)[3]. The rest of the tables correspond to the losses above this difference within the Arctic and Polar regions above 40 degrees geomagnetic latitude. The sporadic-E obscuration loss and the F2 over-the-MUF loss are subtracted from the table value. The residuals of table III are then added to the losses at each frequency for each mode. Auroral losses form the main part of the residual table. Decile values of losses are determined by calculating the E_s obscuration loss and the over-the-MUF losses using the proper decile values of the E_s and E, F1, or F2 mode MUFs. It should be especially noted in this model that the over-the-MUF losses limit the successful operation of radio systems at the higher frequencies; i.e., the mode is always there, but the losses become sufficiently high that the system becomes inoperative. Both the original table and the derived values are decibels with respect to the loss equations given here. If other loss equations are used, the distribution tables must be adjusted. The derivation of these loss equations is given below.

All relationships derived from measurement must include all the various effects of the ionosphere. Electron density, collision frequency, magnetic field, or focusing effects are only "a means to an end" of the analysis and may not necessarily describe the physics involved. The loss equations described herein are referenced to basic transmission loss in free space:

$$L_{bf} = 20 \log (4\pi P'/\lambda) \\ = 32.45 + 20 \log P' + 20 \log f_{ob} \quad (17)$$

where

P' = virtual ray path length in km, (group path),
f_{ob} = oblique frequency in MHz.

The additions to the CCIR ionospheric loss will be normalized to that equation.

10.) D-E Region ionospheric losses

The absorption in the D-E regions of the ionosphere is usually the major loss(after free space) in radio wave propagation via the ionosphere. To describe this effect, Martyn's theorem relating vertical and oblique path and the quasi-longitudinal approximation to the absorption loss (Budden)[15] are used:

$$L(f_{ob}) = L(f_v) \cos \phi_o \quad (18)$$

$$L(f_c) = C \int_{h_o}^{h(f_v)} \frac{N_v/\mu \quad dh}{(f_v + f_H)^2 + (\nu/2\pi)^2} \quad (19)$$

where

C = constant,
h_o = height at bottom of ionosphere,
$h(f_v)$ = height of reflection for frequency f_v,
N = N(h) electron density profile,
υ = υ(h) collision frequency,

μ = refractive index,

f_{ob} = oblique sounding frequency,

f_v = vertical sounding frequency,

f_H = gyrofrequency, (f_L, the longitudinal component of gyrofrequency, is usually put into the equation)

ϕ_o = angle of earth's normal to ray path at 100 km.

Equation (19) can be put into the form of Budden[15]

$$L(f_v) = (\bar{\nu})(h' - h_p) \tag{20}$$

where

$\bar{\nu}$ = effective collision frequency

h' = virtual height of reflection,

h_p = phase height of reflection,

c = velocity of light.

Since h_p is bounded and h' is not, there is a strong dependence on frequency which cannot be explained simply by an inverse-frequency-squared law. The usual method of analysis has been to write (19) in the form (definition of the global absorption parameter A)

$$L(f_v) = \frac{A(f_v)}{(f_v+f_H)^2+(\bar{\nu}/2\pi)^2} \tag{21}$$

Most analyses of absorption are based on estimated $A(f_v)$. This has sometimes been done by assuming non-deviative absorption only, and thereby trying to ignore the frequency dependence. When this is done with a small data base and no adjustment is made for the frequency dependence, the results can be misleading (and possibly inaccurate).

The CCIR absorption equation is based upon the U.S. Army Signal Radio Propagation Agency study (Laitinen and Haydon)[3], with a modification for lower frequencies by Lucas and Haydon[16] . Figure 7 shows the modified function.

The exponent of the frequency term (f_v + f_H) and values for the terms $(\bar{\nu}/2\pi)^2$ and $A(f_v)$ were determined by least square curve fitting. The oblique loss measurements were normalized to

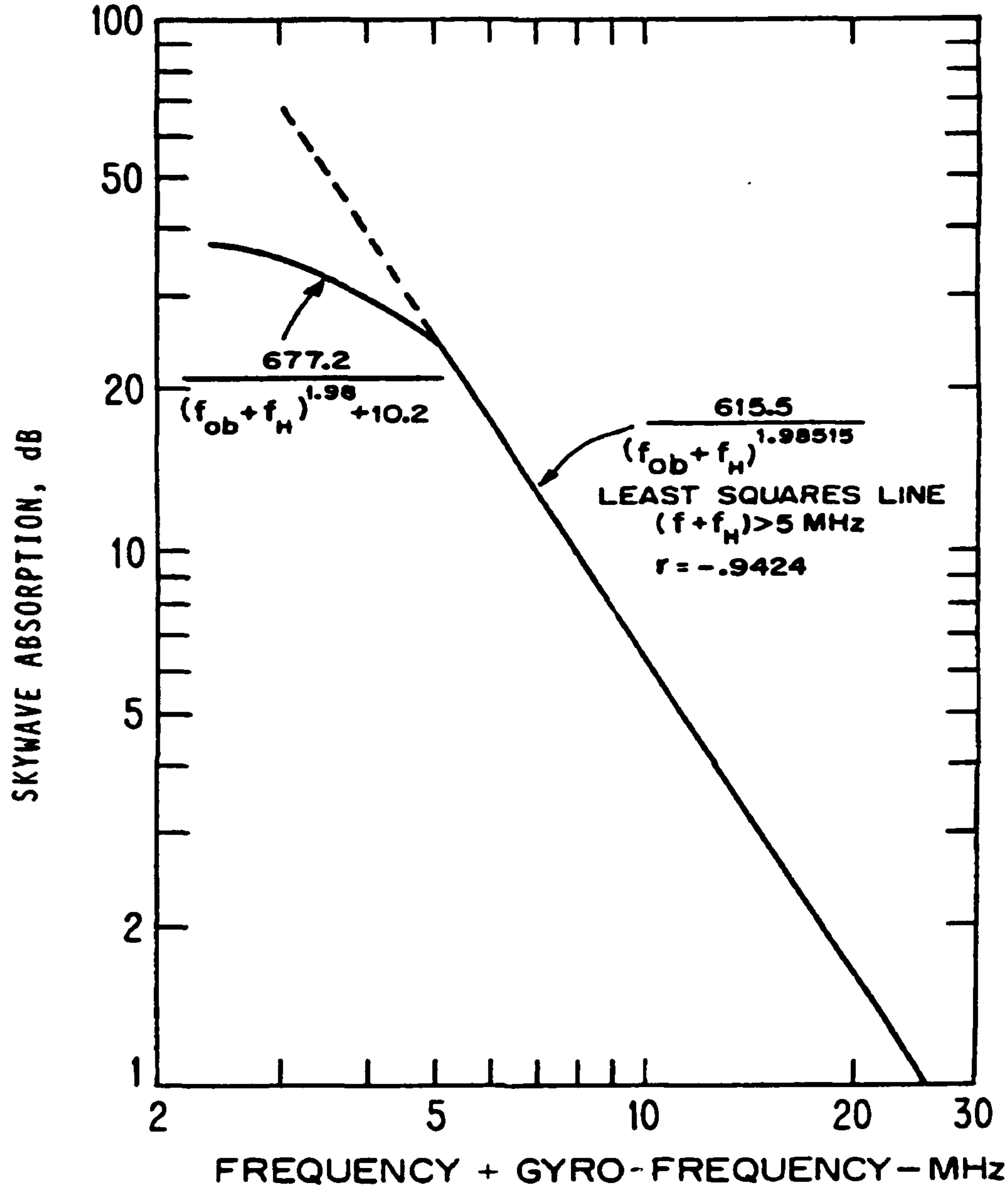

Figure 7 Skywave non-deviative absorption component of system loss.

virtual loss measurements to give a standard comparison method, as well as to expand the data base, by the equation

$$L(f_{ob}) = \frac{L(f_v)[(f_v+f_L)^2+(\bar{\nu}/2\pi)^2]}{[(f_{ob}+f_H)^2+(\bar{\nu}/2\pi)^2]} \sec \Phi_o \qquad (22)$$

The data used were for F-layer modes only . The fitted equation is

$$L(f_{ob}) = \frac{677.2\ I\ \sec\phi_o}{(f_{ob}+f_L)^{1.98}+10.2} \tag{23}$$

That is, the averaged value of $A(f_v)$ is

$$A=677.2\ I$$

where

$$I = .04 + \exp(-2.937 + 0.8445 f_oE) \tag{24}$$

The formula for absorption index I is in terms of f_oE which includes the variation in zenith angle and solar activity. This formula is an inversion of that formerly used to obtain f_oE from I. There have been attempts to modify and replace equation (23) by independent researchers. Schultz and Gallet[27] (implemented in ITS-78 (Barghausen et al.))[28] used the methods described by Piggott[29] to describe A without frequency dependence (non-deviative absorption) on a smaller data base than was used to derive Equation (23), but did not add the frequency dependence suggested by Piggott (essentially the same as Equation (20), but for a parabolic E-layer). George[30] has developed an absorption equation using an $A(f_v)$ which has an implicit (h'- h) curve. The method of supplementing equation (23) described below was based upon area coverage and radar backscatter data and was developed in two steps, first to correct equation (23) for E-layer modes and then for frequency dependence (deviative absorption). It is essentially based upon the suggestion in Piggott and in George, but with the advantage of having the electron density profiles available on a worldwide basis. (See also Rawer[25], Bibl et al[31], and Fejer[32], for further discussion.) The absorption equation (23) contains an averaged value of $A(f_v)$ for F2-layer modes, i.e., the effects of E-region electron density on non-deviative absorption collision frequency (and magnetic field effects, etc.) were averaged in the curve fitting process. Therefore, a correction for E-layer modes was derived:

$$L_c = A + B \log_e (X_e) , \tag{25}$$

where

L_C is the loss correction factor for E modes;
A = 1.359 for $f_oE > 2$ MHz,
A = 1.359 (f_oE - 0.5) / 1.5 for 0.5 < f_oE < 2 MHz,
= 0.0 for f_oE < 0.5 MHz;
B = 8.617 for $f_oE > 2$ MHz,
= 8.617 (f_oE - 0.5) / 1.5 for 0.5 < f_oE < 2 MHz,
= 0.0 for f_oE < 0.5 MHz;

X_e = f_V / f_oE for h > 90 km,
= $f_V(90)$ / f_oE for h < 90 km;
h = true height of reflection;
f_v = equivalent vertical sounding frequency.

The equations for E-mode and F-mode losses assume that the mode goes through the absorbing region (true height of reflection above 95 to 100 km). Equation (25) represents the effect of E-layer losses which were included in Equation (23). When the true height of reflection is below 90 km, which will happen with the complete electron density profiles, the use of Equations (23) and (25) will give losses much higher than those observed. The absorption should reach a maximum and then decrease as the operating frequency is lowered. Theoretically the absorption reaches a maximum at the height where $(\bar{\nu}/2\pi^2 + f_H)$. However the electron density profile available does not represent the lower ionosphere adequately, so this behavior has been introduced into the model in an ad hoc manner by replacing the constant value of $(\bar{\nu}/2\pi)^2$ - 10.2) by a calculated value. When the true height of reflection, h, varies between 70 and 88 km the value of $(\bar{\nu}/2\pi)^2$ varies between 40, the value it would have at a height of 61 km, and 10.2, the value it would have at a height of 64 km. The equation for the height h_v is (h_v does not correspond to any physical parameter)

$$h_v = 61 + 3(h-70)/18. \tag{26}$$

The equation for effective collision frequency is

$$(\bar{\nu}(h_\nu)/(2\pi)^2 = (\nu_o/2\pi)^2 \, exp(-2(h_\nu\text{-}60)/H) \tag{27}$$

where

$$(\nu_o/2\pi)^2 = 63.07$$

$$H = 4.39.$$

The equation (27) gives realistic values for ν. The transformation from h to h_v was derived using measured values of field strength on the Kogani to Akito path (Japan) at operating frequencies of 2.5 and 5.0 MHz, for the year 1970.

Since a complete electron density profile is used, any mode, high- or low-angle, will be considered. To account for the deviative (and spreading) losses of the high-angle modes, the following procedure is used. Deviative losses are considered to be averaged into Equation (23) for those modes with reflection heights less than that at the layer MUF. For modes with reflection heights greater than that at the layer MUF and for modes just past the E-F cusp, a deviative loss term is added. The equation is based on the relationship that the loss is proportional to the product of collision frequency with the difference between group path and phase path, i.e.,

$$A_p(f_\nu) = B(f_\nu)(h'\text{-}h)_N \, sec(\phi_o) \tag{28}$$

where $A_p(f_\nu)$ is the deviative absorption loss in dB and

$$
\begin{aligned}
B(f_v) &= C_E \exp\,[-2(h-70)/y_mE] \quad \text{for the E-layer,}\\
&= C_F \exp\,[-2(h-h_mF2 + y_mF2)/y_mF2] \quad \text{for the F2-layer,}\\
B(f_v) &= C_1 \exp\,[-2(h-h_mF1 + y_mF1)/y_mF1] \quad \text{for the F1-layer and}\\
B(f_v) &= C_2 \exp\,[-2(h-h_mF2 + y_mF2)/y_mF2] \quad \text{for the F2 layer}
\end{aligned}
$$

when the F1-layer is present.

The constants have not been mapped on a worldwide basis as yet. Interim values used are

$$C_E = 0.25,$$
$$C_F = 0.40,$$
$$C_1 = 0.60,$$
$$C_2 = B(f_oF1).$$

In order to preserve continuity at the F1-layer to F2-layer transition, C_2 is the value of $B(f_v)$ with f_v taken as f_oFl. This assures a smooth calculation of loss for all possible electron density profiles. Note that C_F and C_2 are forced to have minimum values of 0.05.

When sporadic-E is present, the loss is supplemented by an E_s obscuration factor as described in section 12.

11.) Loss for propagation above the MUF

The model does not assume that propagation ceases at the junction frequency (or skip distance). It is known that the geometric optics approximation does not suffice in the neighborhood of the skip zone. By using wave methods, it is shown that energy diffracts into the skip region (Bremmer)[33]. However, the observed signals are too strong to be explained in terms of wave propagation at the skip distance. The physical mechanism for the propagation of significant signals within the skip zone (or above the MUF when the distance is fixed) is not completely understood. One possibility is that the ray-path approximation for the calculation of skywave signal paths is probably inadequate since the skywave signal will normally return from a large region of the ionosphere (at least one fresnel zone). As the frequency approaches the MUF, the energy arriving at the sharper angles will tend to penetrate and a portion of the fresnel zone becomes ineffective as a reflector. As the frequency is further increased, less and less of energy is reflected and losses will sharply increase. On the longer paths where the fresnel zone is larger, losses increase slowly as the frequency exceeds the MUF compared to the sharp increase on shorter paths where the fresnel zone is smaller. Other mechanisms may also contribute to the signal propagation and explain the significant signals observed above the MUF. For example, propagation may possibly be explained by scattering from horizontal irregularities in the ionosphere (Budden, 1966). The method used here is based on the empirical statistical method of Philips-Abel (Wheeler)[34] rather than wave theory. The basic assumption is that a reflecting layer of the ionosphere may be considered as composed by quasi-random (quasi-independent) elemental patches of ionization. These elemental patches are considered to be composed of subpatches, each with a classical MUF. The median value of received power is proportional to the probability that there are reflecting areas with elemental classical MUF values

that are equal to or greater than the transmission frequency. Experience indicates that the normal distribution is a fair estimate of the spatial probability of the elemental classical MUF values and that the mean value of this distribution is a fair estimate of the standard MUF. Further, at any given operating frequency there is some probability that the frequency will exceed the median monthly predicted MUF on some days. Thus this loss term includes both the effect of not being below the MUF on some days of the month and the loss on those days when the frequency is above the MUF. So this term is added at all operating frequencies. The equation is

$$L = 10 \log_{10} P \sec(\phi) \tag{29}$$

$$P = \frac{1}{\sqrt{2\pi}} \int_{Z}^{\infty} \exp(-X^2/2)\,dx$$

$$Z = (f_o - f_m)/\sigma$$

f_m is the MUF for the circuit elevation angle and distance (note that f_m is lower for a two-hop mode than for a one-hop mode to the same range). For vertical incidence, the loss is less than 0.5 dB for frequencies less than the FOT, and less than 3 dB for frequencies less than the MUF. Note that all modes from all layers (E, F1, F2, and E_s) now look the same (absorption losses plus over-the-MUF loss). The differ·nce is in the distribution of the MUF's, being narrow for the E and F1, somewhat wider for the F2, and widest for E_s.

Since signal losses are associated with the ratio of the operating frequency to the MUF at a given time, the day-to-day variation of the losses will be dependent upon the day-to-day variation of the MUFs within the month. This results in a dramatic spread in the day-to-day distribution of expected losses near the monthly median MUF. As the frequency is well above the monthly median MUF; e.g., above the HPF only the scatter components remain and the signal is very weak, but the day-today distribution is not great.

12.) Sporadic-E losses

This section discusses the loss models associated with modes of propagation for which ray theory is not valid. The sporadic-E layer was not included in the electron density profile. It is modeled as a thin layer occurring at the height $h'E_s$ (usually 100 to 110 km). Its effect upon modes of propagation passing through it is given by E_s obscuration loss. It is calculated by a method proposed by Phillips[35] and modified to use the now available maps of foEs:

$$L_o = 10 \log_{10}(1-p) \tag{30}$$

where

$$P = \frac{1}{2\pi} \int_z^{\infty} \exp(-x^2)\, dx$$

$$Z = \frac{f_{ob} - f_m E_s}{\sigma}$$

and

$$f_m E_s = f_o Es \sec\phi$$

For modes which have reflected from the sporadic-E layer, the loss is the absorption losses supplemented by a reflection loss (corresponding to the over-the-MUF loss) defined by

$$L_R = 8.91\, P^{-0.7} \tag{31}$$

13.) System loss

The system loss of a radio circuit is defined as the ratio of the signal power available at the receiving antenna terminals relative to that available at the transmitter antenna terminals, in decibels. This excludes any transmitting or receiving antenna transmission line losses, since such losses are considered readily measurable. The system loss does include all the losses in the transmitting and receiving antenna circuits - not only the transmission loss caused by radiation from the transmitting antenna and reradiation from the receiving antenna, but also any ground losses, dielectric losses, antenna loading coil losses, and terminating resistor losses. Antenna gain is taken as antenna power gain which is the product of antenna directive gain in the direction aligned with the propagation path in both elevation and azimuth and of antenna efficiency.

The system loss is summarized as (Rice, et al.)[38]

$$L_s = L_{bf} + L_i + L_g - (G_t + G_r) \text{ (dB)} \tag{32}$$

where

L_{bf} = the basic free-space transmission loss expected between ideal, loss-free,isotropic, transmitting and receiving antennae in free space;

L_i = losses caused by ionospheric absorption, this term includes sporadic E layer obscuration loss, L , for F-layer modes. For all modes, this factor includes the deviative losses at high reflection heights and over-the-MUF loss, as well as the tables of measured deviations which include auroral losses.

L_g = ground reflection losses.

G_t = transmitting antenna power gain relative to an isotropic antenna in free space;

G_r = receiving antenna power gain relative to an isotropic antenna in free space;

In this report, G_t and G_r are in the direction of the propagation path and include all antenna losses, so that $G_t + G_r$ is an approximation of the power gain G_p. The values G_t and G_r are required for any elevation angle, azimuth, and frequency.

The skywave field strength is directly related to the transmission loss, L_b. This is the loss that would be observed if the actual antennas were replaced by ideal, loss-free, isotropic transmitting and receiving antennas. The field strength is:

$$E = 107.2 + 20 \log f_{ob} + G_t + P - L_b \tag{33}$$

where

E = rms field strength in dB referred to one microvolt per meter,

G_t = transmitting antenna gain in the direction of the ray path used to determine L_b (decibels referred to an isotropic antenna).

P = transmitter power delivered to the transmitter antenna in decibels referred to one watt,

f_{ob} = operating frequency in megahertz.

In cases when the reference field strength is 300 millivolts per meter at one kilometer (rms field produced by 1 kW input to a short dipole over perfect earth), the skywave field strength, E, is

$$E = 142.0 + 20 \log f_{ob} - L_b \tag{34}$$

Likewise, when the reference field strength is 222 millivolts per meter at one kilometer, the skywave field strength, E, is

$$E = 139.4 + 20 \log f_{ob} - L_b \tag{35}$$

A semi-empirical method to include recent measurements, especially back-scatter measurement, in the calculation of ionospheric losses has been developed. It includes deviative and non-deviative effects as well as sporadic-E effects. The average effects of magnetic field and of polarization changes are included implicitly as the constants in the equations are taken from measurements which included these effects. The median excess system loss (that loss shown below 40 degrees geomagnetic latitude) is no longer used as it was mainly the average effect of sporadic-E and deviative losses. The remainder of the values from the table III are still used for Arctic losses (Lucas and Haydon)[16].

14.) Antenna gain

The antenna gain is calculated using the take-off vertical radiation angle as calculated from the reflectrices. The specific antenna paterns are stored in arrays of vertical angle gain and horizontal beamwidth for each frequency. The antenna gain routines (e.g. ANT00) must return a power gain for some specific frequency, and vertical and horizontal radiation angle in degrees. The antenna gain routines contained in RADARC are for specific, real antennas and will not be shown in this report.

15.) Ground reflection loss

The ground reflection losses must be estimated for the multi-hop modes of propagation. The RADARC model tests the latitude and longitude of the ground reflection. It then enters a digital representation of the boundaries of the sea and land masses. The reflection area is assumed to be from sea or land and losses such as those shown in figures 8a and 8b are added for each ground reflection. The digital map is a fairly coarse representation of land masses as shown in figure 8a. It is believed to be accurate enough considering that the error in predicting the ground reflection due to gradients in the ionosphere is not taken into account in the program.

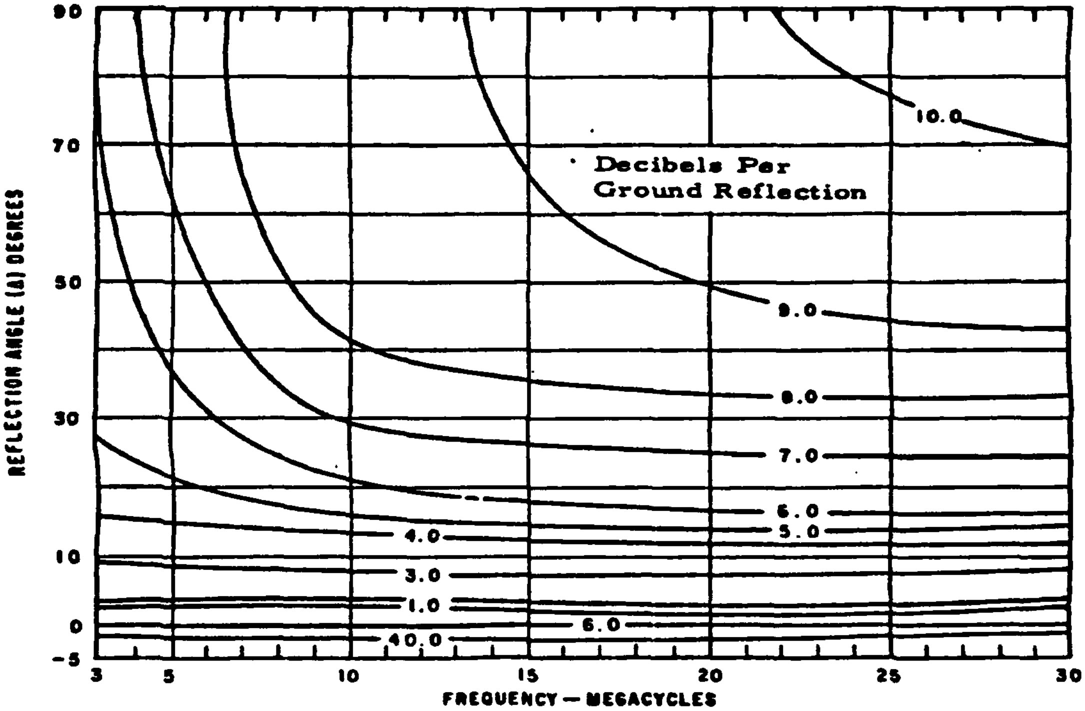

Figure 8a Ground reflection loss for poor earth (ε=4; σ=.001)

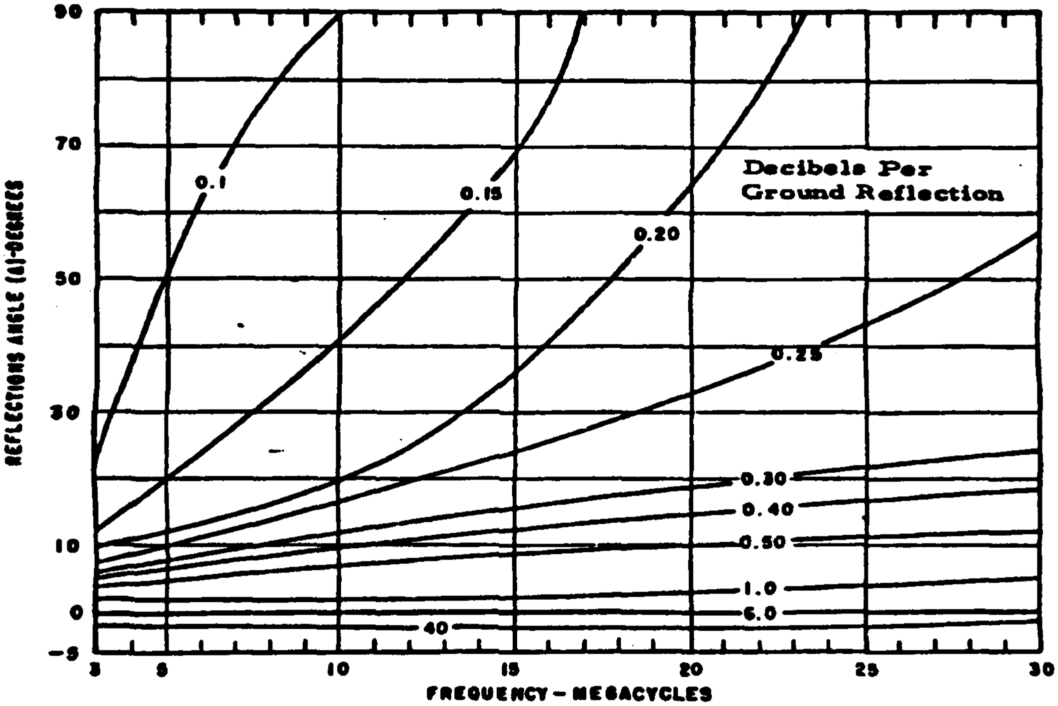

Figure 8b Sea water reflection loss (ε=80; σ=5.0)

16.) Environmental noise

The environmental noise with which a radar must compete is of three different origins.

1.) Atmospheric noise - the noise arising from distant thunderstorm activity.
2.) Galactic noise - the noise received on earth from the galaxy.
3.) Man-made noise - the noise generated by man, ie, electrical power lines, automobile electrical systems, lawnmowers, etc.
4.) A fourth noise can be added that represents the internal noise of the specific radar being used.

The predicted value of atmospheric noise is evaluated from the numerical maps contained in the CCIR report 322-3[37]. The time of year is represented in these maps with four maps over three months each. They are mapped for six hourly time blocks ie, 00-04,04-08,08-12,12-16 and 16-24 LMT. A sample is shown in figure 9. A sample of the frequency dependence is shown in figure 10.

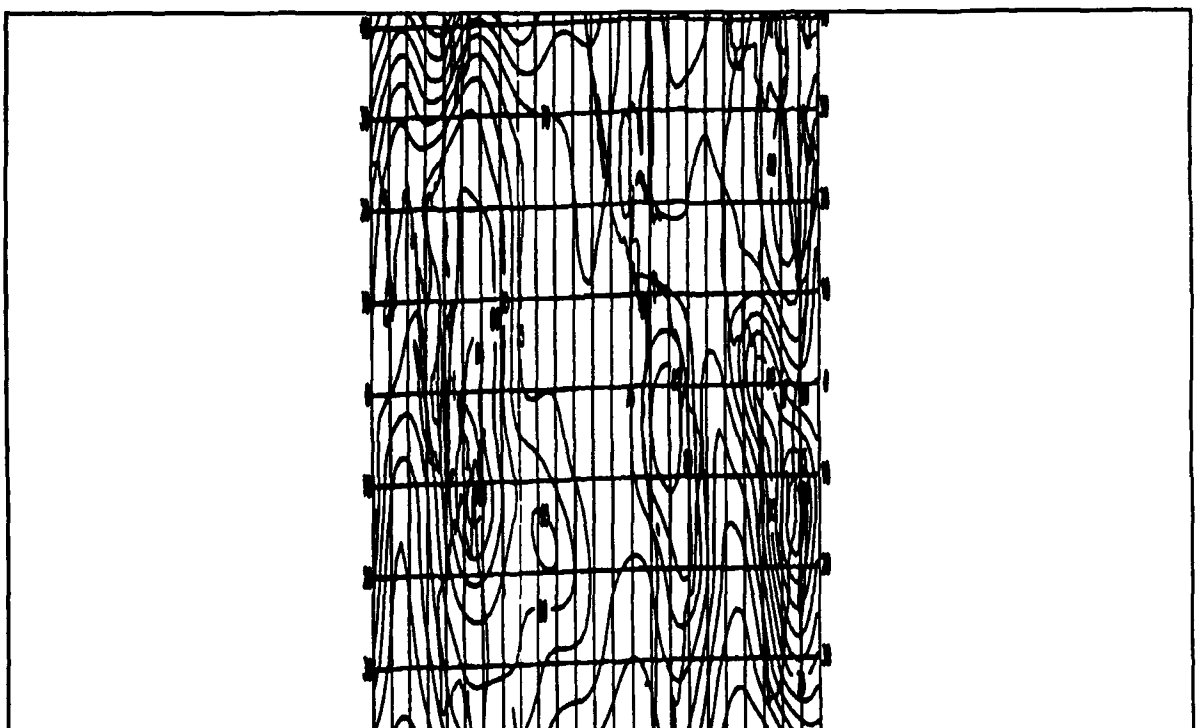

Figure 9 Numerically mapped values of atmospheric radio noise at 1 MHz, F_{am} (dB > (Kt_0b), for Dec-Jan-Feb, 00-04 LMT.

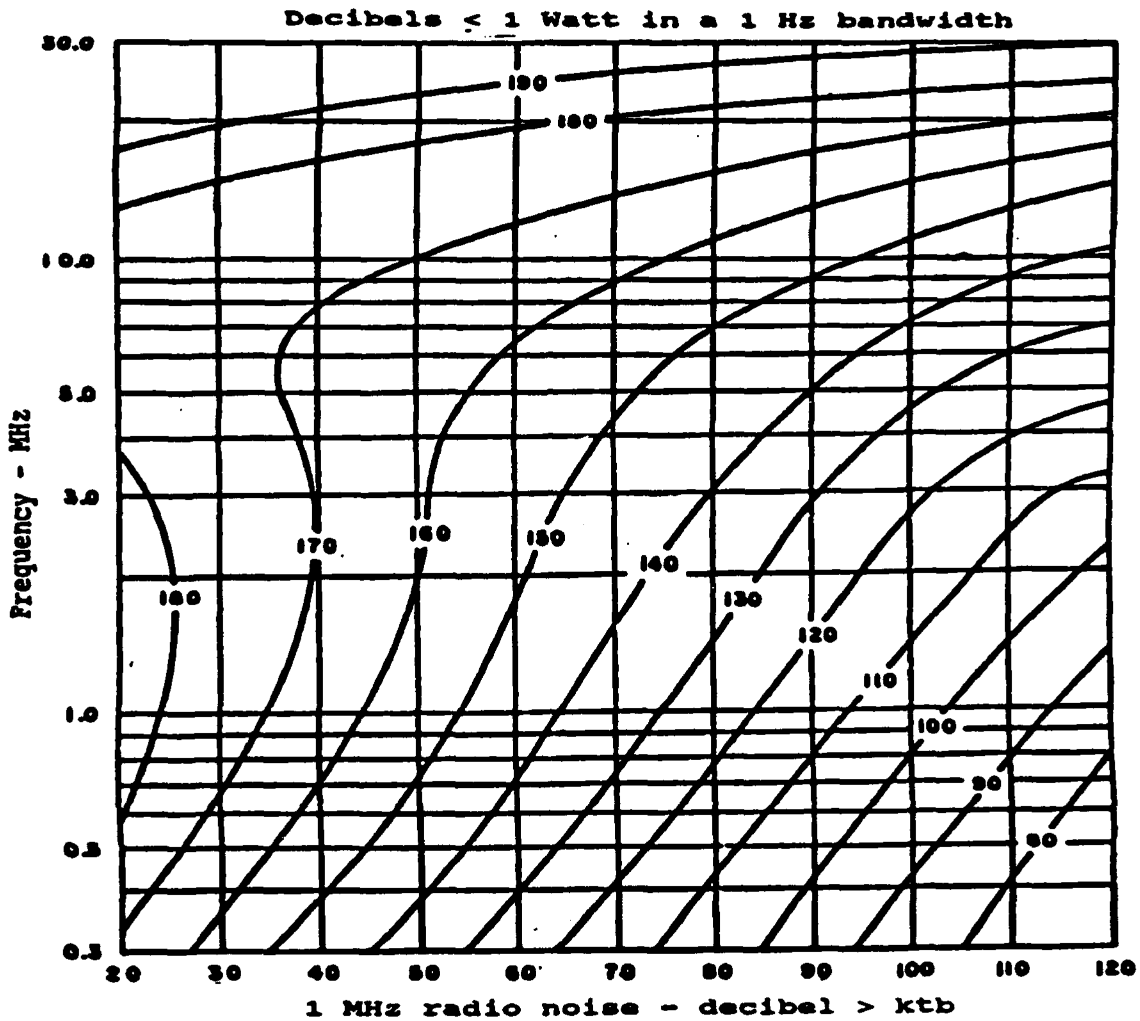

Figure 10 Frequency dependence of the atmospheric radio noise (F_{am}) for 00-04 LMT, Dec-Jan-Feb.

The predicted value of the man-made noise and galactic noise is taken from past measured values. The man-made noise is plotted as a function of population density for those who have no idea what value to use in the predictions. Figure 11 shows these values as a function of "area".

The three or four noise values are predicted for the receiver site in question and the largest one taken as the prevailing value of noise used in the radar equation for calculation of signal-to-noise or ground clutter-to-noise ratio.

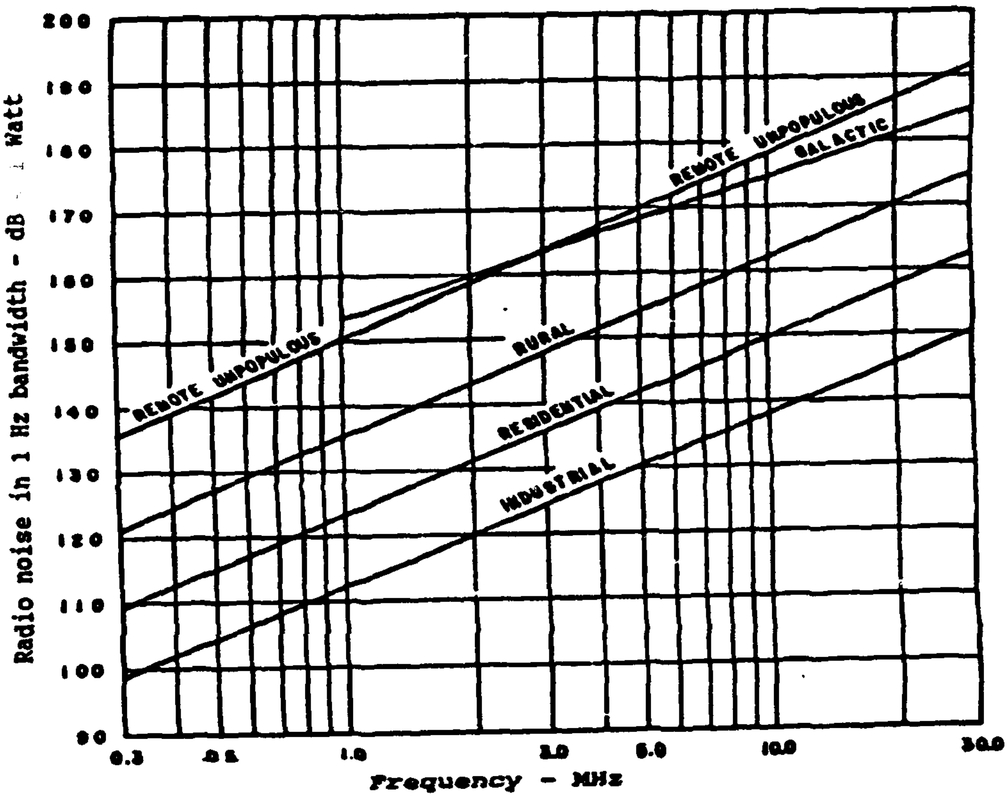

Figure 11 Man-made noise as a function of area population (-dBW)

17.) Backscatter amplitudes and and ray-paths

RADARC is executed for a set of radar parameters, time of day, month of the year, some specific azimuth, transmitter power, etc. and a predetermined maximum number of vertical radiation angles, i.e. 1 to 45 degrees. It is run for each of these specific radiation angles. The result describes a distribution of signal levels along the path for a one-way transmission. The results of these one-way paths can then be inserted into the radar equation to determine the received backscatter amplitude. A complete listing of the variables needed and the form they should be in can be found in a discussion by Headrick[40].

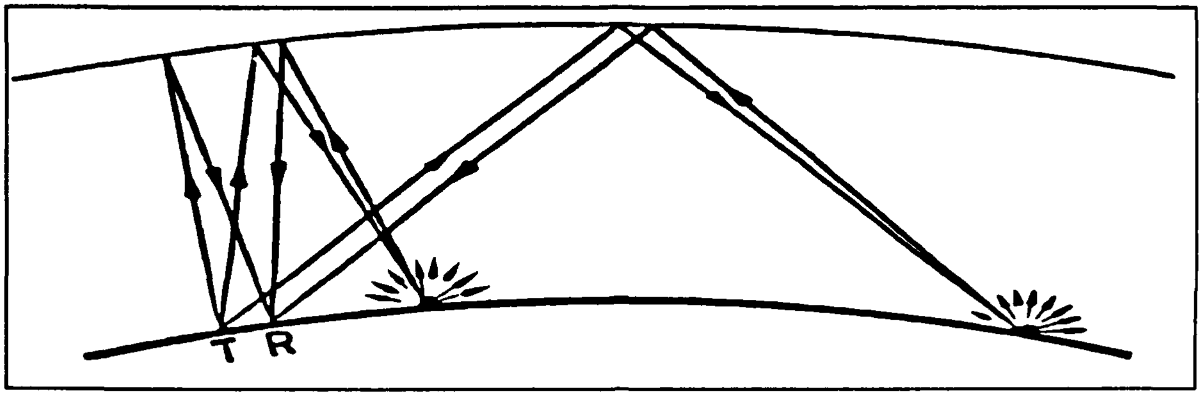

Figure 12 Example raypaths of the backscatter signal

Taking logarithms of the classical radar equation and putting it in the form of the transmission loss equation yields the following equation used in RADARC. The prevailing environmental noise will be added to the equation to yield signal-to-noise or ground clutter-to-noise ratio at the receiver.

$$S/N = POWER + PKAVG + GAIN + LAMLOG + CIT + CAREA + OTH - R4TH - TLOSS - NOISE \tag{36}$$

power = transmitted power - dB > 1 Watt

gain = antenna gain (transmitter + receiver)-dB > isitrope in free space

lamlog = $\lambda^2/4\pi^3$ - dB

r4th = $1/R^4$ losses (from free space loss in section 13)

tloss = system loss from the section 13 (includes antenna gains)

noise = prevailing envirnomental noise (largest of the atmospheric galactic, man-made or radar internal noise)-dBW

carea = reflection coefficient of the surface multiplied by the surface area in meters squared. This can be either the earth area or a target area. dB > 1 $meter^2$

pkavg = peak power/ average power - db (zero for FMCW radar)

oth = radar over the horizon enhancement (usually 12 dB for sea backscatter)

cit = coherent integration time _ this is the time over which a returned waveform is summed at the receiver. dB> 1 sec.

The OTH enhancement is a factor that accounts for multipath and the conductivity of the reflection area. A 6 dB figure seems more reasonable for an air target at altitude than the usual 12 dB and is used by 12 ‹‵˺ for surface targets.

The antenna gains must be in power gain for a signal level prediction. This means the efficiency must be known. To predict signal or ground clutter-to-noise the directive gain may be used.

The sections to follow will show in much detail what is needed for input information to sucessfully execute the program RADARC and detailed output for executed sample input using the program.

18.) Summary

The mathematics associated with the ionospheric profile and ray-path generation are presented for the OTH radar prediction routine RADARC-2. The method of calculating all losses associated with the computed ionosphere is illustrated in detail. The method of including the one-way losses into the radar equation for assessment of OTH radar is shown.

A complete internal description of all the modules forming the Fortran code is included for those wishing to make revisions or corrections to the computer code. The spread Doppler clutter (SDC) code is included in this version of RADARC-2 and is easily invoked in the user friendly input file. The computer program is complete and usable world-wide for OTH radar performance calculations that include environmental noise and range dependent noise (SDC).

The Fortran code allows execution of the program on any machine using a floating point number of at least 32 bits. Outputs can be chosen from many diverse printed tables or printer graphics choices.

PART II

Users guide to RADARC input/output

1.) Input

1.1) Files used by RADARC

All input to RADARC must be available before the program is executed. Several logical assignments must be made as well. There is one input file which contains the run parameters for the program; it is the only file that the user needs to prepare. There are up to seven necessary data files; the exact number depends on the run parameters specified. One scratch file is opened by the program, and it is deleted upon successful execution. These files are:

<u>User prepared</u>	
FOR011.DAT	program control parameters (User specified)
<u>Provided with RADARC</u>	
CGMCS.BIN	geomagnetic database used by CGMCS
HFANT_DIR:ANTXX	optional antenna data file
HFDAT_DIR:GEOMAG.BIN	geomagnetic database used by GEOMAG
HFDAT_DIR:LANDMAP.BIN	digitized map of major land masses
HFDAT_DIR:MON.BIN	monthly longterm ionospheric database
HFDAT_DIR:MONNOISE.BIN	monthly noise maps
HFDAT_DIR:YMCOEF.BIN	maps of the ratio H_m/Y_m for parabolic layers
<u>Created/destroyed by RADARC</u>	
FOR099	scratch file created/deleted by RADARC

<u>The necessary logical assignments are:</u>

FOR011	The user input <u>file</u>, if it has any name other than FOR011.dat or is not located in the default directory from which RADARC is run.
HFANT_DIR	The <u>directory</u> location of the antenna data files.
HFDAT_DIR	The <u>directory</u> location of all data files except those two specified above.
FOR010	A primary output <u>file</u>; assignment is optional.
FOR032	A primary output <u>file</u>; assignment is optional.
FOR034	A secondary output <u>file</u>; assignment is optional.

These assignments can be accomplished under Digital VMS with the following statements. The user must replace the term with the angle brackets with the appropriate specification; the brackets are omitted.

```
$ASSIGN <[user_directory]user_input_file> FOR011
$ASSIGN <[antenna_dir]> HFANT_DIR
$ASSIGN <[antenna_dir]> HFDAT_DIR
$ASSIGN <[user_directory]user_output_file_1> FOR010
```

```
$ASSIGN <[user_directory]user_output_file_2> FOR032
$ASSIGN <[user_directory]user_output_file_3> FOR034
```

1.2) Details of user-specified run parameter file

The user-specified input file consists of a list of keywords, some with arguments. The keywords are listed, one per line, with spaces delimiting keywords and arguments. Any line may be made a comment by inserting an exclamation point (!). No portion of the line to the right of the exclamation point will be read; entire lines may be commented by putting the exclamation point in column 1. Neither blank lines nor lines without a recognizable keyword have any effect. The keywords and their associated arguments are described below, in alphabetical order. A sample input file follows.

ANTTYPE Keyword to select the antenna. Takes 1 value. The value may be positive or negative. If negative, its absolute value is used as the two-way gain. If positive, it is a built-in antenna type to be used in calculating the two-way gain. See the appropriate antenna routine (subroutine antXX). The usages are mutually exclusive, and the last one input is used.

ex: anttype -50 ! Constant 2-way gain of 50 dB.
anttype 12! Internal routine ant12 is used.

default: ANTTYPE -50

AZIMUTH This key allows the user to specify the 'look' azimuth of the radar, in decimal degrees clockwise from geographic north. Takes 1 value.

default: AZIMUTH 77.

CIT Specifies the coherent integration time, seconds. Takes a single value.

default: CIT 1.0

ECLUT, IECLUT May also be IECLUT, either way it takes a single floating point argument, which is a multiplier for e clutter magnitude. Intended to reflect specific ionospheric information only, and be left equal to 1 or 0 the rest of the time.

default: ECLUT 0.

EMULATE This keyword is a sort of meta-key: it takes no arguments and defines a group of variables to be set in accordance with an earlier version of radarc. The effect is immediate and overrides preceding keywords, but not subsequent keywords.The variables affected, and their values after this key is used, are:

SCRPLT - SCRPLT status reverts to SNRPLT

CCRPLT - CCRPLT status reverts to CNRPLT
LIMHOP 2 - only 2 hops are predicted
AREAS 2 - 2 ionospheric sample areas are use
STEP 1400 - No sample is drawn at 0 distance;sample areas are at 1400 and 2800.

default: inactive

FEC, HE, YME
F1C, HF1, YMF1
F2C, HF2, YMF2

These parameters can be used to dictate a complete description of the regular layers of the ionosphere. Two values are associated with each parameter. The first specifies the sample area to be associated with the input value; the second is the input value itself. Defining the ionosphere at unused sample areas has no effect. Up to ten sample areas may be defined.

FEC - E layer critical frequency.
F1C - F1 layer critical frequency.
F2C - F2 layer critical frequency.
HE- Height of maximum ionization, E layer.
HF1 - Height of maximum ionization, F1 layer.
HF2 - Height of maximum ionization, F2 layer.
YME - Semithickness of a parabolic E layer
YMF1- Semithickness of a parabolic F1 layer
YMF2- Semithickness of a parabolic F2 layer

default: by default these parameters are calculated.

FCLUT, IFCLUT May also be IFCLUT, either way it takes a real argument, which is a multiplier for f clutter magnitude. It is intended to reflect specific ionospheric information only, and be left equal to 1 or 0 the rest of the time.

default: FCLUT 0.

FESL,FESM,FESU These parameters can be used to dictate the sporadic E layer. Two values are associated with each parameter. The first specifies the sample area to be associated with the input value; the second is the input value itself. Defining the ionosphere at unused sample areas has no effect. Up to ten sample areas may be defined. Note that these parameters specify the Es layer in a manner which differs from the regular modes.

FESL- Lower decile of Es critical frequency distribution.

CCRPLT - CCRPLT status reverts to CNRPLT
LIMHOP 2 - only 2 hops are predicted
AREAS 2 - 2 ionospheric sample areas are use
STEP 1400 - No sample is drawn at 0 distance;sample areas are at 1400 and 2800.

default: inactive

FEC, HE, YME
F1C, HF1, YMF1
F2C, HF2, YMF2

These parameters can be used to dictate a complete description of the regular layers of the ionosphere. Two values are associated with each parameter. The first specifies the sample area to be associated with the input value; the second is the input value itself. Defining the ionosphere at unused sample areas has no effect. Up to ten sample areas may be defined.

FEC - E layer critical frequency.
F1C - F1 layer critical frequency.
F2C - F2 layer critical frequency.
HE- Height of maximum ionization, E layer.
HF1 - Height of maximum ionization, F1 layer.
HF2 - Height of maximum ionization, F2 layer.
YME - Semithickness of a parabolic E layer
YMF1- Semithickness of a parabolic F1 layer
YMF2- Semithickness of a parabolic F2 layer

default: by default these parameters are calculated.

FCLUT, IFCLUT May also be IFCLUT, either way it takes a real argument, which is a multiplier for f clutter magnitude. It is intended to reflect specific ionospheric information only, and be left equal to 1 or 0 the rest of the time.

default: FCLUT 0.

FESL,FESM,FESU These parameters can be used to dictate the sporadic E layer. Two values are associated with each parameter. The first specifies the sample area to be associated with the input value; the second is the input value itself. Defining the ionosphere at unused sample areas has no effect. Up to ten sample areas may be defined. Note that these parameters specify the Es layer in a manner which differs from the regular modes.

FESL- Lower decile of Es critical frequency distribution.

FESM- median of Es critical frequency distribution.
FESU- upper decile of Es critical frequency distribution.

default: by default these parameters are calculated.

FOE, FOF1, FOF2, FOES

These parameters are layer critical frequency multipliers, to be used to customize the program when specific data about the ionosphere is at hand. Generally, these should be set to 1, except for foEs which is set to .7. Each key takes a single value.

defaults: FOE1.0, FOF1 1.0, FOF2 1.0, FOES 0.7

FREQ, FREQMAX, FREQMIN, FREQSTEP

The prediction may be run for a single frequency, using the 'freq' keyword, or a range of frequencies from 'freqmin' to 'freqmax' in 'freqstep' MHz intervals. The two usages are mutually exclusive. Each key takes 1 value.

default: FREQMIN 5.0, FREQMAX 28.0, FREQSTEP 1.0

GROUND, SLANT An output option, these two parameters are mutually exclusive and only the last will be used. The keyword takes no argument and specifies whether slant or ground range will be used in the plots of CNR/SNR vs. range.

default: GROUND

HOPS, HOPLIM, LIMHOP

These keywords are synonyms. They designate how many hops out the program will calculate. The original radarc used 2 only. Now up to 4 are allowed. Takes 1 argument

default: LIMHOP 2

KFAC K factor is the local magnetic index used in ionospheric clutter calculations. Takes 1 argument.

default: KFAC 1.0

KP Kp is the planetary magnetic index, which is used in calculations of ionospheric clutter and in the calculation of the arctic oval. If this value is negative the oval will not be calculated, but the absolute value will still be used for ionospheric clutter calculations.Takes 1 value.

default: KP -3

LSCAN Scan loss multiplier; takes 1 argument.

default: LSCAN 0

MONTH Specifies the month to be predicted. Takes 1 value.

default: MONTH 1

ORTHOAPT Aperture of the orthogonality effect; takes 1 argument. The aperture is the largest deviation from orthogonality that produces clutter. The magnitude of the clutter will be sin-function interpolated from zero at a deviation outside ORTHOAPT to ORTHOMAG at orthogonality.

default: ORTHOAPT 0.0

ORTHOMAG Maximum value of orthogonality induced ionospheric clutter. Takes 1 argument.

default: ORTHOMAG 0.0

PRINTOUT An output option taking 1 argument; the three values (1, 2, or 3) are mutually exclusive and only the last will be used. The output formats available, and the printout option that specifies them, are:

All printouts

fortran unit 10
- rayset tables up to limhop, regular modes
- rayset tables up to 2 hops, sporadic E modes

fortran unit 30
- vertical ionograms, by sample area
- range coverage, amplitude vs time delay, by frequency (two-part figure, if necessary)
- oblique ionograms (2 ionograms at different scales)
- combined raysets table

printouts 2 and 3 only

fortran unit 32
- range coverage part 1, amplitude vs time delay, by mode
- angle coverage part 1, amplitude vs time delay,

by mode

range coverage part 2 (if necessary), amplitude vs time delay, by mode

angle coverage part 2 (if necessary), amplitude vs time delay, by mode

printout 3 only

fortran unit 34

echo internal values of input

miscellaneous diagnostic information from ymap,lecden, fobby, setion, and setplt.

default: printout 1

SYSLOS Specifies loss due to radar signal processing and other losses not specifically included elswhere, dB.

default: SYSLOS 0.0

PULSEWIDTH Specifies pulsewidth to be used in the prediction, in microseconds. Takes a single value. This is required for earth backscatter area calculation. RADARC calculates SNR on an average power basis; therefore, signal bandwidth is not required.

default: PULSEWIDTH 120.0

SAMPLES, AREAS

This optional parameter specifies the number of sample areas to use. the keywords are synonymous. Take 1 argument.

default: SAMPLES 10

SAMPLE_STEP, AREA_STEP, STEP

These optional synonymous parameters specify the spacing between sample areas. takes 1 argument.

default: 700 km

SITELAT The geographic north latitude of the transmitter in decimal degrees. Takes two values: the first is numeric,the second is a single character north/south indicator. An 'S' will override the sign of the numeric value and result in a point in the southern hemisphere. An 'N' or an omitted value will result in an interpretation from North. e.g. +north,-south.

ex:
SITELAT -25. S yields 25 degrees south
SITELAT 25. S yields 25 degrees south
SITELAT 25. N yields 25 degrees north
SITELAT -25. N yields 25 degrees south
SITELAT 25. yields 25 degrees north

default: SITELAT 38.655 N

SITELONG The geographic west longitude of the transmitter in decimal degrees. Takes 2 values: the first is numeric, the second is a single character East/West indicator. The 'E' or 'W' characters are additive with the sign of the numeric.

ex:
SITELONG -77. W yields 77 degrees east
SITELONG -77. E yields 77 degrees west

default: SITELONG 77.5 W

SNRPLT, CNRPLT, SCRPLT, CCRPLT

Output options; the following options are, like many keywords in this list, mutually exclusive, and only the last will be used. The keywords take no arguments and specify:

SNRPLT - signal-to-noise ratio vs. range. This is the ratio of the signal associated with the return from the target to the noise at the receiver.

CNRPLT - clutter-to-noise ratio vs. range.This is the ratio of the signal associated with the ground or sea return to the noise at the receiver.

SCRPLT - signal-to-ionospheric clutter ratio vs. range. This is the ratio of the signal associated with the return from the target to the greater of noise at the receiver or ionospheric clutter.

CCRPLT - clutter-to-ionospheric clutter ratio vs.range. This is the ratio of the signal associated with the ground or sea return to the greater of noise at the receiver or ionospheric clutter.

default: SNRPLT

SUNSPOT, FLUX Solar flux and sunspot are used for the same sorts of calculations. If either is input the program will calculate the other according to the relationship

below, to be used

FLUX = ((406.37+SUNSPOT)**2-93918.4)/1117.3
SUNSPOT = SQRT(93918.4+1117.3*FLUX)-406.37

as called for; therefore only one of these is required. In fact, only one can be used, because the last one input will cause the recalculation of previous flux/sunspot values. Each keyword takes a single value.

<u>default: SUNSPOT 70.</u>

TARSIZE, TARTYPE

The radar target may be included as a fixed target size using 'TARSIZE', in dB above 1 sq. meter, or as a built-in target type, using 'TARTYPE'. Tartype and tarsize are mutually exclusive: the last one encountered will be used. Each key requires 1 value.

<u>default: TARSIZE 20</u>

TIME, TIME_START, TIME_STOP, TIME_SKIP

24 hour GMT time at the transmitter for which a prediction is desired. Like the frequency, this parameter may be constant (use 'TIME'), or defined as a loop from 'TIME_START' to 'TIME_STOP' by steps of 'TIME_SKIP'. Each key requires 1 value.

<u>default: TIME 0.</u>

TXPOWER Allows specification of the transmitter power of the radar in kW. Takes a single value.

<u>default: TXPOWER 0.2</u>

WT The receive weighting factor; takes 1 argument.

<u>default: WT 1.0</u>

XNOISE

Receiver CCIR noise type if zero or negative, as given below,or noise in dB below 1 watt if positive and not equal to 5. When equal to 5, the specified noise is the greater of the natural noise and an approximate internal noise calculated in the program. Takes a single value.

CCIR man-made noise
- -1 Industrial
- -2 Residential
- -3 Rural
- -4 Remote

Internal noise options
- -5 use internal noise only (no natural noise)
- +5 manmade noise source is internal noise

<u>default: +5</u>

YEAR

If the oval is turned off, this is cosmetic only, but with the oval turned on this is necessary, and is used to figure solar epoch. Takes 1 value.

<u>default: YEAR 1989</u>

The following sample input file is a legal, unambiguous file, though messy.

```
! an ! indicates a comment or comment line
! file: SAMPLE.INP
sitelat 51.44 N          ! latitude of transmitter decimal degree N+, S-
sitelong  79.16 W        ! longitude of transmitter W+, E-
azimuth 275.             ! 'look' azimuth deg CW from North
hops 2                   ! calculate only 2 hops of predictions
FREQMIN 5.               ! you may select to run the prediction for a single
FREQMAX 28.              ! frequency, using the "freq" keyword, or a range of
FREQSTEP 1               ! frequencies from "freqmin" to "freqmax" in "freqstep"
!FREQ 18.                ! intervals. the two usages are mutually exclusive.
txpower 200.             ! KW)
pulsewidth 120           ! Microseconds
cit 3.1                  ! Coherent Integration Time, seconds
xnoise -5                ! Receiver Noise type if negative, noise in dB below
!                          1 watt if positive
!
! antenna type may be positive or negative. if negative, it's absolute
! value is used as the two-way gain. If positive, it is an antenna type to be
! used in calculating the two-way gain. See the appropriate antenna
! routine (subroutine antXX). The usages are mutually exclusive, and the
! last one input is used.
! anttype -50 ! Constant gain antenna, 2-way gain = abs(-50)
anttype 12 ! Antenna type, last one controls
MONTH 6                  ! Month Number (1 - 12)
! GMT time at transmitter
TIME 24 ! GMT time (1-24)
!time_start 2
!time_stop 3
!time_skip 1
! if the oval is off, this is cosmetic only, but with the oval on this is
! used to figure solar epoch.
year 1991                ! Needed for arctic oval
! solar flux and sunspot are used for the same sort of calculations. If flux
! is input the program will calculate a sunspot number to use as called for.
! therefore only one of these need be used in the deck.  In fact only one can
! be used in the deck because the last one input will cause the recalculation
! of previous flux/sunspot values.
!flux 70 ! Can use either flux or sunspot number
sunspot 100.
! Kp is the planetary magnetic index, which is used in calculations
! of ionospheric clutter and in the calculation of the arctic oval. If
!this value is negative the oval will not be calculated, but the absolute
```

```
! value will still be used for ionospheric clutter calculations.
Kp 5 ! Magnetic activity (1-7) needed for arctic oval/trough
!
Kp -1.7 ! Negative value turns off oval, absolute value still
!        used in Elkin's clutter algorithms, last one controls
!
! layer critical frequency multipliers, to be used to customize the program
! when specific information about the ionosphere is known.  Generally, these
! should be set to 1, except for foEs which is set to .7
!
foE  1.0 ! foE  multiplicative factor, default = 1.0
foF1 1.0 ! foF1 multiplicative factor, default = 1.0
foF2 1.0 ! foF2 multiplicative factor, default = 1.0
foEs .7 ! foEs multiplicative factor, default = .70
! tartype and tarsize are mutually exclusive, only the last one entered
! will be used
tartype -1 ! Target type, can use type or size
tarsize 17.0 ! Target size, dB above 1 sq. meter, last one controls
! output options, the following three options are, like many inputs in
! this list, mutually exclusive and only the last will be used.
areas 2 ! this optional parameter specifies the number of sample areas to use
area_step 1400. ! this optional parameter specifies the spacing between sample
!              areas.
scrplt 1.0 ! Signal/max( ionospheric clutter, noise), last one controls
snrplt 1.0 ! Signal/noise plots, last one controls
ccrplt 1.0 ! Clutter/noise plots, can use cnrplt or snrplt
cnrplt 1.0 ! Signal/max( ionospheric clutter, noise), last one controls
!          the argument is ignored
!
! output options, the following two options are mutually exclusive
! and only the last will be used.  The argument is ignored.
ground 1.0 ! CNR or SNR plots vs range, last one controls
slant 1.0  ! CNR or SNR plots vs range, can use slant or ground
! output options, the following three options are mutually exclusive
! and only the last will be used.
printout 1 ! Normal print out, last one controls
printout 2 ! Individual frequencies printed out plus printout = 1
!printout 3 ! Diagnostic print out plus printout = 2 and 1
!
WT 1.0   ! receive weighting factor
KFAC 5   ! K factor is a local magnetic index used in ionospheric clutter
!        calculations
LSCAN 0  ! scan loss multiplier
FCLUT  0.01 ! may also be IFCLUT, either way it is a real multiplier for f clutter
```

```
!          magnitude. Should be used to reflect specific ionospheric
!          information only, and be left equal to 1 or 0 the rest of the time.
ECLUT  0.01 ! may also be IECLUT, either is a real multiplier for e clutter
!          magnitude. Should be used to reflect specific ionospheric
!          information only, and be left equal to 1 or 0 the rest of the time.
ORTHOMAG .01 ! Maximum value of orthogonality induced ionospheric clutter
ORTHOAPT 0.1 ! Aperture of orthogonality effect;
!            largest deviation from orthogonality that produces clutter.
!
!       the ORTHO variables are left at .01 in this case because if they are
!       set to zero, some calculations are never done. This is reasonable
!       unless you want to see the magnetic aspect angle (labelled ORTHO deg
!       on the output), as we do lately.
!
!       This file is a legal, unambiguous input file just as it stands.  All
!       mutually exclusive options are resolved by considering the last
!       input only.
!
!EMULATE  ! good idea to put this last to avoid accidental redefinition
```

2.) Output

The output from RADARC consists of a number of tables and graphs spread over three files. The **PRINTOUT** keyword determines which output is produced. The files are on fortran units 10, 32, and 34. These files will be named FOR010.DAT, FOR032.DAT, and FOR034.DAT, unless a logical assignment was made to reassign the unit before the program was executed. These files will be referred to by their respective logical file names below.

2.1) FOR010: Single frequency rayset tables

These tables show the basic geometry calculated by the program together with the associated propagation characteristics. Each table has a heading which reports the basic run parameters, and a body which reports the geometry and propagation characteristics at each vertical take-off angle. The regular mode tables differ slightly from the sporadic-E mode tables. The items appearing in each table also vary with the run options selected. Regular mode example rayset tables are presented in figures 1a,b. Sporadic-E mode example rayset tables are presented in figures 2a,b.

Values in the body of the tables are identified by abreviated column headings. These abreviations are described below:

COLUMN 1	This unlabelled column holds mode information. The mode symbols used in this output are E, 1, 2, S, and +, representing the regular E, F_1, F_2,sporadic E, and over-the-MUFmodes, respectively. For example, 'E2' denotes a regular E mode followed by an F2 mode.
ANG or ELANG	the vertical take-off angle in degrees associated with the predicted rayset geometry.
HITE	the 'average' virtual height in kilometers for all hops.
TIME	the total time delay in milliseconds for the ground range at the end of the last hop.
GND	the ground range in nautical miles to the end of the last hop.
SLANT	the (1-way) slant range in nautical miles to end of last hop.
C-AREA	the radar cross section (RCS) of the sea/ground resolution cell at the end of the last propagation hop. This RCS is the product of the resolution cell area and the surface scattering coefficient, σ^o. In this sample σ^o = -29 dB.
T-AREA	the size of the target in db relative to 1 square meter.
R4TH	total two way free space loss to the end of the final hop.

ABS	total non-deviative absorption.
DEV	total deviative absorption.
GNDLOS	total ground reflection losses in db; omitted from 1 hop tables.
GT+GR	combined transmit and receive antenna gain, in db.
CPINC	the increment to ionospheric clutter power in db due to orthogonality of the raypath to the Earth's magnetic field. It is associated with the input key words: **SCRPLT,CCRPLT, ORTHOAPT, ORTHOMAG.** 'CPINC' only appears on the output when scrplt or ccrplt is selected, and its magnitude depends on orthoapt and orthomag.
ORTHO	the angle between the raypath and the Earth's magnetic field at the target range. This column appears only when **SCRPLT** or **CCRPLT** is selected.
PROBE	the predicted probability of ionospheric clutter originating in the E layer. This column appears only when **SCRPLT** or **CCRPLT** is selected.
PROBF	the predicted probability of ionospheric clutter originating in the F layer. This column appears only when **SCRPLT** or **CCRPLT** is selected.
CPDB	the total ionospheric clutter power resulting from the predictions of CPINC, PROBE, and PROBF. It is compared to other noise sources and the greatest becomes the limiting noise for the prediction. This column appears only when **SCRPLT** or **CCRPLT** is selected.
REF or LOSS	total reflection losses on E_s modes
P-REC	the predicted signal from the target, associated with T-AREA, in dbW.
CNR	the ratio of the signal associated with C-AREA to the greatest noise source. (CNR and SNR differ by the same amount as C-AREA and T-AREA.
SNR	the ratio of the signal associated with T-AREA to the greatest noise source. (CNR and SNR differ by the same amount as C-AREA and T-AREA.
S	the ionospheric sample area associated with the last hop. It is 'associated' because the properties of this sample area result in the most self-consistent prediction geometry available. When the number of sample areas is limited, the sample area chosen may not result in a perfectly self-consistent prediction. For example, imagine the program is calculating the characteristics of the second hop of a two-

hop prediction. The characteristics of the first hop are known. Let us say the second hop begins at a ground distance of 5000 nm. The properties of the sample area located at 2500 nm suggest that the reflection area for the second hop should be around 7500 nm (geometry just like the first hop). So the program performs a calculation for the sample area located nearest 7500 nm, but the properties of that sample area suggest that the true reflection area may be nearer 9000 nm. If no other sample is available, then the program must use the sample at 7500 nm and a small inconsistency must be tolerated. Were other samples available the program would attempt to home on the best one. In practice this effect is small unless the ionosphere is changing rapidly between sample areas.

ONE HOP RAY SET TABLE   JUN SSN=100   TIME=24 UT   FREQUENCY= 13.000 MHZ   17-DEC-1992 11:36
TRANSMITTER: 51.4N LAT -79.2E LON   ANTTYP   12
BEARING=275.00 DEG   BEAMWIDTH= 0.63 DEG   NOISE=-175.54 DBW
PEAK PWR=   53.0 DBW   LAMBDA SQ/4PI CUBE=   -5.7 DBSM   AURORAL LOSS= 6.5 DB
AVG/PK PWR= 0.0 DB.   OTH ENHANCEMENT= 6.0 DB   INT. TIME=   3.10 SEC (OR 4.9 DB)

LOSS COLUMN IS SUM OF AURORAL, ABS, DEV, OBF LOSSES
CNR(DB) IS SAME AS SNR(DB) BELOW EXCEPT C-AREA(BACKSCATTER AREA) IS USED FOR TARGET SIZE
SNR(DB)=PEAK PWR + GT+GR + LAMBDA SQ/4PI CUBED - R4TH - LOSS - NOISE + TARGET SIZE
+ AVERAGE/PEAK PWR RATIO + OTH PATH ENHANCEMENT + INTEGRATION TIME
ALL EXPRESSEDIN DB FOR A ONE HERTZ BANDWIDTH

	TIME MSEC	ELANG DEG	HITE KM	GND NM	SLANT NM	GT+GR DB	C-AREA DBSM	T-AREA DBSM	R4TH DBM	ABS DB	DEV DB	OBF DB	LOSS DB	P-REC DBW	CNR DB	SNR DB	
E	16.12	0.0	113.6	1289.	1302.	0.0	57.8	17.0	255.3	19.7	3.5	0.0	29.7	-169.0	6.5	-34.3	2
E	14.72	1.0	113.8	1176.	1189.	15.8	57.4	17.0	253.7	19.6	3.5	0.9	29.7	-152.0	23.5	-16.9	2
E	13.49	2.0	114.5	1076.	1090.	31.5	57.0	17.0	252.2	19.4	3.6	0.0	29.5	-134.9	40.6	0.6	2
E	12.43	3.0	115.8	990.	1004.	37.1	56.7	17.0	250.8	18.9	3.8	0.0	29.2	-128.0	47.5	7.9	2
E	11.52	4.0	117.6	916.	931.	42.8	56.3	17.0	249.5	18.4	4.0	0.0	28.9	-121.0	54.5	15.2	2
E	10.75	5.0	120.0	853.	868.	45.5	56.1	17.0	248.3	17.7	4.3	0.0	28.5	-117.1	58.5	19.4	2
E	10.41	6.0	128.0	823.	841.	48.1	55.9	17.0	247.7	17.0	5.1	0.0	28.6	-114.1	61.5	22.5	2
1	16.86	7.0	273.5	1307.	1362.	49.1	58.0	17.0	256.1	16.3	10.0	10.6	43.4	-134.2	41.4	0.3	2
1	16.03	8.0	274.6	1238.	1295.	50.0	57.8	17.0	255.2	15.5	9.0	9.6	40.6	-129.8	45.8	5.0	2
1	15.41	9.0	279.3	1186.	1245.	51.0	57.7	17.0	254.5	14.8	7.5	8.5	37.3	-125.0	50.5	9.9	2
1	15.03	10.0	288.8	1152.	1215.	52.0	57.6	17.0	254.1	14.1	7.4	7.5	35.5	-121.9	53.7	13.1	2
1	15.35	11.0	315.7	1168.	1240.	52.2	57.7	17.0	254.4	13.5	9.7	6.5	36.2	-122.6	53.0	12.3	2
2	18.02	12.0	410.9	1349.	1456.	52.5	58.4	17.0	257.2	12.8	7.8	5.6	32.7	-120.9	54.7	13.3	2
2	16.59	13.0	389.1	1239.	1340.	52.5	58.0	17.0	255.8	12.2	4.6	4.8	28.1	-115.2	60.3	19.3	2
2	15.58	14.0	378.3	1160.	1259.	52.5	57.8	17.0	254.7	11.7	4.3	4.0	26.5	-112.8	62.8	22.0	2
2	14.80	15.0	372.9	1098.	1196.	52.0	57.6	17.0	253.8	11.2	3.4	3.3	24.4	-110.5	65.0	24.4	2
2	14.21	16.0	371.8	1049.	1148.	51.4	57.4	17.0	253.1	10.7	3.4	2.7	23.3	-109.3	66.2	25.8	2
2	13.73	17.0	373.2	1008.	1110.	50.7	57.3	17.0	252.5	10.3	3.3	2.2	22.2	-108.6	67.0	26.7	2
2	13.37	18.0	377.2	975.	1080.	49.9	57.2	17.0	252.0	9.8	3.4	1.8	21.5	-108.2	67.3	27.1	2
2	13.12	19.0	384.4	950.	1060.	49.2	57.1	17.0	251.7	9.5	3.6	1.4	21.0	-108.1	67.4	27.3	2
2	12.93	20.0	393.2	929.	1045.	48.6	57.1	17.0	251.5	9.1	3.9	1.1	20.6	-108.2	67.3	27.2	2
2	12.89	21.0	406.4	918.	1041.	48.0	57.1	17.0	251.4	8.8	4.5	0.9	20.6	-108.7	66.9	26.8	2
2	12.97	22.0	424.3	915.	1048.	47.4	57.2	17.0	251.5	8.5	5.1	0.6	20.7	-109.4	66.1	25.9	2
2	13.25	23.0	449.4	925.	1070.	46.9	57.3	17.0	251.9	8.2	6.3	0.5	21.5	-110.9	64.6	24.3	2
2	13.95	24.0	492.1	961.	1127.	46.4	57.6	17.0	252.8	7.9	8.4	0.4	23.2	-113.7	61.8	21.2	2
2	17.43	25.0	652.6	1165.	1408.	46.2	58.6	17.0	256.7	7.7	19.3	0.3	33.7	-127.4	48.2	6.6	2
+	11.55	26.0	424.3	790.	933.	45.9	56.8	17.0	249.5	7.4	27.8	0.0	41.7	-130.2	45.3	5.5	2
+	11.25	27.0	424.3	762.	909.	45.8	56.7	17.0	249.0	7.2	37.2	0.0	50.9	-139.1	36.4	-3.3	2
+	10.96	28.0	424.3	735.	885.	45.7	56.7	17.0	248.6	7.0	47.8	0.0	61.3	-149.2	26.3	-13.4	2
+	10.68	29.0	424.3	710.	863.	45.4	56.6	17.0	248.1	6.8	59.1	0.0	72.4	-160.3	15.2	-24.4	2
+	10.42	30.0	424.3	686.	842.	45.0	56.5	17.0	247.7	6.6	70.6	0.0	83.7	-171.7	3.9	-35.7	2
+	10.18	31.0	424.3	663.	822.	44.3	56.5	17.0	247.3	6.4	82.0	0.0	95.0	-183.3	-7.7	-47.2	2
+	9.94	32.0	424.3	641.	803.	43.6	56.4	17.0	246.9	6.3	93.1	0.0	105.9	-194.5	-19.0	-58.4	2
+	9.72	33.0	424.3	619.	785.	42.8	56.4	17.0	246.5	6.1	103.7	0.0	116.3	-205.5	-30.0	-69.3	2
+	9.51	34.0	424.3	599.	768.	41.9	56.3	17.0	246.1	6.0	103.8	0.0	116.3	-206.0	-30.4	-69.7	2
+	9.31	35.0	424.3	579.	752.	41.3	56.3	17.0	245.8	5.8	103.8	0.0	116.1	-206.1	-30.6	-69.9	2
+	9.12	36.0	424.3	560.	737.	40.6	56.2	17.0	245.4	5.7	103.8	0.0	116.0	-206.3	-30.8	-70.0	2
+	8.94	37.0	424.3	542.	722.	40.3	56.2	17.0	245.1	5.6	103.8	0.0	115.9	-206.2	-30.7	-69.9	2
+	8.77	38.0	424.3	525.	708.	40.0	56.2	17.0	244.7	5.5	103.8	0.0	115.8	-206.1	-30.5	-69.7	2
+	8.60	39.0	424.3	508.	695.	39.5	56.2	17.0	244.4	5.4	103.8	0.0	115.7	-206.2	-30.6	-69.8	2
+	8.45	40.0	424.3	49.	683.	39.0	56.2	17.0	244.1	5.3	103.8	0.0	115.6	-206.2	-30.7	-69.8	2
+	8.30	41.0	424.3	476.	671.	37.2	56.1	17.0	243.8	5.2	103.8	0.0	115.5	-207.7	-32.2	-71.3	2
+	8.16	42.0	424.3	460.	659.	35.3	56.1	17.0	243.5	5.1	103.8	0.0	115.4	-209.2	-33.7	-72.8	2
+	8.02	43.0	424.3	446.	648.	33.7	56.1	17.0	243.2	5.0	103.8	0.0	115.3	-210.4	-34.9	-74.0	2
+	7.89	44.0	424.3	431.	638.	32.2	56.1	17.0	242.9	4.9	103.8	0.0	115.2	-211.6	-36.1	-75.2	2

FIGURE 1a: Example regular mode rayset table. (one hop)

TWO HOP RAY SET TABLE JUN SSN=100 TIME=24 UT FREQUENCY= 13.000 MHZ 17-DEC-1992 11:36
TRANSMITTER: 51.4N LAT -79.2E LON ANTTYP 12
BEARING=275.00 DEG BEAMWIDTH= 0.63 DEG NOISE=-175.54 DBW
PEAK PWR= 53.0 DBW LAMBDA SQ/4PI CUBE= -5.7 DBSM AURORAL LOSS= 6.5 DB
AVG/PK PWR= 0.0 DB. OTH ENHANCEMENT= 6.0 DB INT. TIME= 3.10 SEC (OR 4.9 DB)

LOSS COLUMN IS SUM OF AURORAL, ABS, DEV, OBF, GNDLOS LOSSES
CNR(DB) IS SAME AS SNR(DB) BELOW EXCEPT C-AREA(BACKSCATTER AREA) IS USED FOR TARGET SIZE
SNR(DB)=PEAK PWR + GT+GR + LAMBDA SQ/4PI CUBED - R4TH - LOSS - NOISE + TARGET SIZE
+ AVERAGE/PEAK PWR RATIO + OTH PATH ENHANCEMENT + INTEGRATION TIME
ALL EXPRESSEDIN DB FOR A ONE HERTZ BANDWIDTH

	TIME MSEC	ELANG DEG	HITE KM	GND KM	SLANT KM	GT+GR DB	C-AREA DBSM	T-AREA DBSM	R4TH DBM	ABS DB	DEV DB	OBF DB	GNDLOS DB	LOSS DB	P-REC DBW	CNR DB	SNR DB
EE	31.94	0.0	111.5	2555.	2580.	0.0	60.8	17.0	267.2	46.6	6.0	0.0	12.0	71.0	-219.2	-43.7	-87.4
EE	29.14	1.0	111.7	2328.	2354.	15.8	60.4	17.0	265.6	46.3	6.0	0.0	0.8	59.7	-191.0	-15.4	-58.8
EE	26.66	2.0	112.2	2127.	2154.	31.5	60.0	17.0	264.0	45.7	6.2	0.0	3.2	61.6	-175.9	-0.4	-43.3
EE	24.50	3.0	113.3	1952.	1980.	37.1	59.6	17.0	262.6	44.7	6.6	0.0	2.4	60.1	-167.7	7.8	-34.8
EE	22.65	4.0	114.7	1801.	1830.	42.8	59.3	17.0	261.2	43.3	7.1	0.0	1.9	58.8	-159.7	15.8	-26.4
EE	21.07	5.0	116.8	1673.	1703.	45.5	59.0	17.0	260.0	41.8	7.6	0.0	1.5	57.5	-154.8	20.8	-21.2
EE	20.06	6.0	121.8	1588.	1621.	48.1	58.8	17.0	259.1	40.1	8.7	0.0	1.3	56.7	-150.7	24.9	-16.9
1E	25.95	7.0	195.9	2024.	2096.	49.1	59.9	17.0	263.6	38.4	13.9	10.6	1.2	70.6	-167.0	8.5	-34.4
1E	24.66	8.0	198.2	1919.	1993.	50.0	59.7	17.0	262.7	36.7	13.5	9.6	1.0	67.3	-162.1	13.4	-29.2
1E	24.10	9.0	206.5	1867.	1947.	51.0	59.6	17.0	262.3	35.0	12.4	8.5	6.6	68.9	-163.4	13.1	-29.5
11	28.24	10.0	266.4	2169.	2282.	52.0	60.3	17.0	265.0	33.3	19.7	16.3	7.2	83.0	-177.6	-2.0	-45.3
11	27.86	11.0	279.5	2128.	2251.	52.2	60.3	17.0	264.8	31.7	19.0	14.0	7.8	79.0	-173.1	2.4	-40.8
21	30.07	12.0	328.9	2270.	2429.	52.5	60.6	17.0	266.1	30.3	16.8	11.8	0.7	66.1	-160.9	14.6	-29.0
21	28.35	13.0	321.7	2134.	2291.	52.5	60.4	17.0	265.1	28.9	12.9	9.8	0.7	58.7	-152.8	22.7	-20.6
21	27.44	14.0	324.9	2057.	2217.	52.5	60.2	17.0	264.5	27.6	13.2	8.1	9.4	64.8	-158.4	17.1	-26.1
22	31.49	15.0	402.4	2326.	2544.	52.0	60.9	17.0	266.9	26.4	9.8	6.6	9.9	59.2	-155.1	20.5	-23.4
22	25.72	16.0	392.4	2187.	2401.	51.4	60.6	17.0	265.9	25.2	9.6	5.3	0.6	47.1	-142.8	32.7	-10.9
22	28.42	17.0	388.7	2081.	2297.	50.7	60.5	17.0	265.1	24.2	8.7	4.2	0.5	44.1	-139.9	35.7	-7.8
22	27.50	18.0	389.9	2002.	2222.	49.9	60.3	17.0	264.6	23.2	8.7	3.2	0.5	42.2	-138.3	37.2	-6.1
22	26.83	19.0	394.5	1940.	2167.	49.2	60.3	17.0	264.1	22.3	8.8	2.5	0.5	40.6	-137.1	38.5	-4.8
22	26.36	20.0	401.8	1892.	2130.	48.6	60.2	17.0	263.8	21.5	9.4	1.9	0.5	39.7	-136.6	39.0	-4.2
22	26.14	21.0	413.0	1861.	2112.	48.0	60.2	17.0	263.7	20.7	10.3	1.4	0.5	39.3	-136.6	38.9	-4.3
22	26.24	22.0	429.8	1850.	2120.	47.4	60.2	17.0	263.8	20.0	11.5	1.0	0.4	39.5	-137.3	38.2	-5.0
22	26.67	23.0	452.8	1861.	2155.	46.9	60.3	17.0	264.0	19.3	13.6	0.7	0.4	40.6	-139.1	36.4	-6.9
22	27.79	24.0	490.0	1924.	2246.	46.4	60.6	17.0	264.8	18.7	17.2	0.5	0.4	43.3	-142.8	32.7	-10.9
22	32.49	25.0	602.8	2185.	2625.	46.2	61.3	17.0	267.5	18.1	31.8	0.4	13.8	70.6	-172.4	3.2	-41.1
++	23.38	26.0	429.8	1597.	1889.	45.9	59.9	17.0	261.8	17.5	56.4	0.0	0.4	80.8	-178.5	-3.0	-45.9
++	22.76	27.0	429.8	1541.	1839.	45.8	59.8	17.0	261.3	17.0	75.0	0.0	0.4	98.9	-196.3	-20.8	-63.6
++	22.17	28.0	429.8	1487.	1792.	45.7	59.7	17.0	260.8	16.5	96.0	0.0	14.6	133.6	-230.8	-55.2	-98.0
++	21.62	29.0	429.8	1436.	1747.	45.4	59.7	17.0	260.4	16.0	118.4	0.0	14.8	155.8	-253.0	-77.4	-120.1
++	21.09	30.0	429.8	1387.	1704.	45.0	59.6	17.0	260.0	15.6	141.4	0.0	15.1	178.5	-275.7	-100.1	-142.7
++	20.60	31.0	429.8	1341.	1664.	44.3	59.5	17.0	259.6	15.2	164.1	0.0	15.3	201.1	-298.6	-123.0	-165.6
++	20.12	32.0	429.8	1296.	1626.	43.6	59.5	17.0	259.2	14.8	186.2	0.0	15.5	223.0	-320.9	-145.3	-187.8
++	19.68	33.0	429.8	1253.	1590.	42.8	59.4	17.0	258.8	14.5	207.4	0.0	15.7	244.0	-342.4	-166.8	-209.3
++	19.25	34.0	429.8	1212.	1556.	41.9	59.4	17.0	258.4	14.1	208.9	0.0	15.9	245.3	-344.2	-168.7	-211.1
++	18.85	35.0	429.8	1172.	1523.	41.3	59.3	17.0	258.0	13.8	208.9	0.0	16.0	245.2	-344.3	-168.8	-211.2
++	18.46	36.0	429.8	1134.	1492.	40.6	59.3	17.0	257.7	13.5	208.9	0.0	16.2	245.0	-344.5	-169.0	-211.3
++	18.10	37.0	429.8	1097.	1462.	40.3	59.3	17.0	257.3	13.2	208.9	0.0	16.3	244.9	-344.4	-168.9	-211.1
++	17.75	38.0	429.8	1062.	1434.	40.0	59.3	17.0	257.0	12.9	208.9	0.0	16.5	244.8	-344.3	-168.7	-211.0
++	17.42	39.0	429.8	1027.	1408.	39.5	59.2	17.0	256.6	12.7	208.9	0.0	16.6	244.6	-344.3	-168.8	-211.0
++	17.11	40.0	429.8	994.	1382.	39.0	59.2	17.0	256.3	12.4	208.9	0.0	16.7	244.5	-344.4	-168.8	-211.0
++	16.80	41.0	429.8	962.	1358.	37.2	59.2	17.0	256.0	12.2	208.9	0.0	16.8	244.4	-345.8	-170.3	-212.5
++	16.52	42.0	429.8	931.	1335.	35.3	59.2	17.0	255.7	12.0	208.9	0.0	16.9	244.3	-347.3	-171.8	-213.9
++	16.25	43.0	429.8	901.	1313.	33.7	59.2	17.0	255.4	11.8	208.9	0.0	17.0	244.1	-348.4	-172.9	-215.1
++	15.98	44.0	429.8	872.	1292.	32.2	59.2	17.0	255.2	11.6	208.9	0.0	17.1	244.0	-349.6	-174.1	-216.3

FIGURE 1b: Example regular mode rayset table. (two hop)

ONE HOP RAY SET TABLE   JUN SSN=100   TIME=24 UT   FREQUENCY= 13.000 MHZ   17-DEC-1992 11:36
TRANSMITTER: 51.4N LAT -79.2E LONG   ANTTYP   12
BEARING = 275.00 DEG   BEAMWIDTH =   0.63 DEG   NOISE = -175.54 DBW
PEAK PWR =   53.0 DBW   LAMBDA SQ/4PI CUBE =   -5.7 DBSM
AVG/PK PWR =   0.0 DB.   OTH ENHANCEMENT =   6.0 DB   INT. TIME =   3.10 SEC (OR 4.9 DB)

LOSS COLUMN IS EQUAL TO REF LOSS
CNR(DB) IS SAME AS SNR(DB) BELOW EXCEPT C-AREA(BACKSCATTER AREA) IS USED FOR TARGET SIZE
SNR(DB) = PEAK PWR + GT+GR + LAMBDA SQ/4PI CUBED - R4TH - LOSS - NOISE + TARGET SIZE
+ AVERAGE/PEAK PWR RATIO + OTH PATH ENHANCEMENT + INTEGRATION TIME
ALL EXPRESSED IN DB FOR A ONE HERTZ BANDWIDTH

	TIME MSEC	ELANG DEG	HITE KM	GND NM	SLANT NM	GT+GR DB	C-AREA DBSM	T-AREA DBSM	R4TH DBM	REF DB	LOSS DB	P-REC DBW	CNR DB	SNR DB
S	15.86	0.0	110.0	1269.	1281.	0.0	57.7	17.0	255.0	39.1	39.1	-183.1	-2.7	-43.4
S	14.45	1.0	110.0	1155.	1167.	15.8	57.3	17.0	253.4	39.2	39.2	-166.2	14.2	-26.1
S	13.17	2.0	110.0	1051.	1064.	31.5	56.9	17.0	251.8	39.4	39.4	-149.5	31.0	-8.9
S	12.02	3.0	110.0	959.	972.	37.1	56.5	17.0	250.2	39.9	39.9	-143.1	37.4	-2.2
S	11.00	4.0	110.0	876.	889.	42.8	56.2	17.0	248.7	40.8	40.8	-137.2	43.2	4.1
S	10.10	5.0	110.0	802.	816.	45.5	55.8	17.0	247.2	42.4	42.4	-135.1	45.4	6.6
S	9.30	6.0	110.0	737.	751.	48.1	55.4	17.0	245.7	44.2	44.2	-133.1	47.3	8.9
S	8.59	7.0	110.0	679.	694.	49.1	55.1	17.0	244.4	44.9	44.9	-131.8	48.7	10.6
S	7.96	8.0	110.0	628.	643.	50.0	54.8	17.0	243.0	45.9	45.9	-130.9	49.6	11.8
S	7.40	9.0	110.0	582.	598.	51.0	54.5	17.0	241.8	47.2	47.2	-130.3	50.2	12.7
S	6.91	10.0	110.0	542.	558.	52.0	54.2	17.0	240.6	49.1	49.1	-130.2	50.2	13.1
S	6.47	11.0	110.0	506.	523.	52.2	53.9	17.0	239.4	51.5	51.5	-131.5	48.9	12.0
S	6.08	12.0	110.0	473.	491.	52.5	53.7	17.0	238.3	54.6	54.6	-133.5	46.9	10.3
S	5.72	13.0	110.0	444.	462.	52.5	53.4	17.0	237.3	58.5	58.5	-136.7	43.8	7.4
S	5.41	14.0	110.0	418.	437.	52.5	53.2	17.0	23[illegible].3	63.5	63.5	-140.9	39.6	3.4
S	5.12	15.0	110.0	394.	414.	52.0	53.0	17.0	23[illegible].4	69.6	69.6	-146.8	33.6	-2.3
S	4.87	16.0	110.0	372.	393.	51.4	52.8	17[illegible]	[illegible]	77.3	77.3	-154.3	26.1	-9.6
S	4.63	17.0	110.0	353.	374.	50.7	52.6	17.0	233.6	86.9	86.9	-164.0	16.4	-19.1
S	4.42	18.0	110.0	334.	357.	49.9	52.4	17.0	232.8	98.9	98.9	-176.1	4.3	-31.1
S	4.22	19.0	110.0	318.	341.	49.2	52.2	17.0	232.0	113.9	113.9	-191.2	-10.7	-45.9
S	4.05	20.0	110.0	303.	327.	48.6	52.1	17.0	231.3	132.7	132.7	-210.1	-29.6	-64.7
S	3.88	21.0	110.0	289.	314.	48.0	51.9	17.0	230.6	156.5	156.5	-233.8	-53.4	-88.3
S	3.73	22.0	110.0	275.	302.	47.4	51.8	17.0	229.9	186.6	186.6	-263.9	-83.5	-118.3
S	3.59	23.0	110.0	263.	290.	46.9	51.6	17.0	229.2	225.0	225.0	-302.3	-121.9	-156.5
S	3.47	24.0	110.0	252.	280.	46.4	51.5	17.0	228.6	274.2	274.2	-351.5	-171.1	-205.6
S	3.35	25.0	110.0	241.	270.	46.2	51.4	17.0	228.0	337.7	337.7	-414.8	-234.4	-268.8
S	3.24	26.0	110.0	231.	261.	45.9	51.3	17.0	227.4	420.2	420.2	-497.1	-316.6	-350.9
S	3.13	27.0	110.0	222.	253.	45.8	51.2	17.0	226.8	452.8	452.8	-529.3	-348.9	-383.1
S	3.04	28.0	110.0	213.	245.	45.7	51.1	17.0	226.3	452.6	452.6	-528.8	-348.3	-382.4
S	2.95	29.0	110.0	205.	238.	45.4	51.0	17.0	225.8	452.4	452.4	-528.5	-348.1	-382.1
S	2.86	30.0	110.0	197.	231.	45.0	50.9	17.0	225.3	452.2	452.2	-528.3	-347.8	-381.7
S	2.79	31.0	110.0	190.	225.	44.3	50.8	17.0	224.8	452.0	452.0	-528.4	-347.9	-381.8
S	2.71	32.0	110.0	183.	219.	43.6	50.8	17.0	224.3	451.9	451.9	-528.5	-348.1	-381.8
S	2.64	33.0	110.0	176.	214.	42.8	50.7	17.0	223.9	451.7	451.7	-528.8	-348.4	-382.1
S	2.58	34.0	110.0	170.	208.	41.9	50.7	17.0	223.4	451.6	451.6	-529.2	-348.7	-382.4
S	2.52	35.0	110.0	164.	203.	41.3	50.6	17.0	223.0	451.4	451.4	-529.3	-348.8	-382.4
S	2.46	36.0	110.0	158.	199.	40.6	50.6	17.0	222.6	451.3	451.3	-529.5	-349.0	-382.6
S	2.40	37.0	110.0	153.	194.	40.3	50.5	17.0	222.2	451.2	451.2	-529.3	-348.8	-382.4
S	2.35	38.0	110.0	147.	190.	40.0	50.5	17.0	221.9	451.1	451.1	-529.2	-348.7	-382.2
S	2.30	39.0	110.0	142.	186.	39.5	50.4	17.0	221.5	451.0	451.0	-529.2	-348.7	-382.2
S	2.26	40.0	110.0	138.	182.	39.0	50.4	17.0	221.1	450.9	450.9	-529.3	-348.8	-382.2
S	2.21	41.0	110.0	133.	179.	37.2	50.4	17.0	220.8	450.8	450.8	-530.7	-350.3	-383.7
S	2.17	42.0	110.0	128.	175.	35.3	50.4	17.0	220.5	450.7	450.7	-532.2	-351.7	-385.1
S	2.13	43.0	110.0	124.	172.	33.7	50.4	17.0	220.1	450.6	450.6	-533.3	-352.9	-386.3
S	2.09	44.0	110.0	120.	169.	32.2	50.4	17.0	219.8	450.5	450.5	-534.5	-354.1	-387.4

FIGURE 2a: Example sporadic-E mode rayset table. (one hop)

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TWO HOP RAY SET TABLE   JUN SSN=100  TIME=24 UT  FREQUENCY= 13.000 MHZ                               17-DEC-1992 11:36
TRANSMITTER:   51.4N LAT  -79.2E LONG           ANTTYP   12
BEARING = 275.00 DEG  BEAMWIDTH =   0.63 DEG  NOISE = -175.54 DBW
PEAK PWR =    53.0 DBW  LAMBDA SQ/4PI CUBE =   -5.7 DBSM
AVG/PK PWR =   0.0 DB.  OTH ENHANCEMENT =   6.0 DB   INT. TIME =   3.10 SEC (OR  4.9 DB)

LOSS COLUMN IS SUM OF REF AND GNDLOS LOSSES
CNR(DB) IS SAME AS SNR(DB) BELOW EXCEPT C-AREA(BACKSCATTER AREA) IS USED FOR TARGET SIZE
SNR(DB) = PEAK PWR + GT+GR + LAMBDA SQ/4PI CUBED - R4TH - LOSS - NOISE + TARGET SIZE
          + AVERAGE/PEAK PWR RATIO + OTH PATH ENHANCEMENT + INTEGRATION TIME
          ALL EXPRESSED IN DB FOR A ONE HERTZ BANDWIDTH
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	TIME MSEC	ELANG DEG	HITE KM	GND NM	SLANT NM	GT+GR DB	C-AREA DBSM	T-AREA DBSM	R4TH DBM	REF DB	GNDLOS DB	LOSS DB	P-REC DBW	CNR DB	SNR DB
SS	31.72	0.0	110.0	2538.	2563.	0.0	60.7	17.0	267.1	44.1	12.0	95.2	-248.2	-67.8	-111.5
SS	28.89	1.0	110.0	2309.	2334.	15.8	60.3	17.0	265.4	44.0	0.8	84.1	-220.1	-39.7	-83.0
SS	26.34	2.0	110.0	2102.	2128.	31.5	59.9	17.0	263.8	43.9	1.7	84.9	-204.0	-23.6	-66.5
SS	24.05	3.0	110.0	1917.	1943.	37.1	59.5	17.0	262.2	43.7	2.4	86.0	-198.2	-17.8	-60.3
SS	22.01	4.0	110.0	1752.	1778.	42.8	59.2	17.0	260.7	43.6	3.2	87.5	-193.0	-12.6	-54.7
SS	20.20	5.0	110.0	1604.	1632.	45.5	58.8	17.0	259.2	43.7	3.9	90.1	-191.7	-11.3	-53.1
SS	18.59	6.0	110.0	1474.	1502.	48.1	58.4	17.0	257.8	44.3	4.6	93.2	-191.1	-10.7	-52.1
SS	17.17	7.0	110.0	1358.	1388.	49.1	58.1	17.0	256.4	45.8	5.3	96.0	-191.9	-11.4	-52.6
SS	15.92	8.0	110.0	1256.	1286.	50.0	57.8	17.0	255.1	48.2	6.0	100.0	-194.0	-13.5	-54.3
SS	14.80	9.0	110.0	1165.	1196.	51.0	57.5	17.0	253.8	49.3	6.6	103.1	-195.2	-14.7	-55.2
SS	13.82	10.0	110.0	1084.	1116.	52.0	57.2	17.0	252.6	50.9	7.2	107.2	-197.4	-16.9	-57.1
SS	12.94	11.0	110.0	1011.	1045.	52.2	56.9	17.0	251.5	53.3	7.8	112.6	-201.6	-21.2	-61.1
SS	12.15	12.0	110.0	946.	982.	52.5	56.7	17.0	250.4	56.6	8.3	119.5	-207.5	-27.0	-66.7
SS	11.45	13.0	110.0	888.	925.	52.5	56.4	17.0	249.4	61.0	8.9	128.4	-215.5	-35.1	-74.5
SS	10.82	14.0	110.0	835.	874.	52.5	56.2	17.0	248.4	66.8	9.4	139.6	-226.0	-45.6	-84.8
SS	10.25	15.0	110.0	788.	828.	52.0	56.0	17.0	247.4	74.4	9.9	153.9	-240.1	-59.7	-98.7
SS	9.73	16.0	110.0	745.	786.	51.4	55.8	17.0	246.5	84.5	10.4	172.2	-258.2	-77.7	-116.5
SS	9.26	17.0	110.0	705.	748.	50.7	55.6	17.0	245.7	97.7	10.8	195.4	-281.5	-101.1	-139.7
SS	8.84	18.0	110.0	669.	714.	49.9	55.4	17.0	244.9	115.2	11.2	225.3	-311.6	-131.1	-169.5
SS	8.45	19.0	110.0	636.	683.	49.2	55.2	17.0	244.1	138.4	11.7	263.9	-350.3	-169.8	-208.0
SS	8.09	20.0	110.0	605.	654.	48.6	55.1	17.0	243.3	169.6	12.0	314.3	-400.7	-220.2	-258.3
SS	7.77	21.0	110.0	577.	628.	48.0	54.9	17.0	242.6	211.6	12.4	380.5	-466.9	-286.4	-324.4
SS	7.47	22.0	110.0	551.	603.	47.4	54.8	17.0	241.9	269.0	12.8	468.4	-554.8	-374.4	-412.1
SS	7.19	23.0	110.0	527.	581.	46.9	54.7	17.0	241.3	348.2	13.1	586.3	-672.7	-492.2	-529.9
SS	6.93	24.0	110.0	504.	560.	46.4	54.5	17.0	240.6	456.4	13.4	744.0	-830.4	-649.9	-687.5
SS	6.69	25.0	110.0	483.	541.	46.2	54.4	17.0	240.0	456.0	13.8	807.5	-893.6	-713.2	-750.6
SS	6.47	26.0	110.0	463.	523.	45.9	54.3	17.0	239.4	455.7	14.0	889.9	-975.8	-795.4	-832.7
SS	6.27	27.0	110.0	444.	506.	45.8	54.2	17.0	238.9	455.4	14.3	922.5	-999.9	-827.6	-864.8
SS	6.08	28.0	110.0	427.	491.	45.7	54.1	17.0	238.3	455.1	14.6	922.3	-999.9	-827.0	-864.1
SS	5.90	29.0	110.0	410.	476.	45.4	54.0	17.0	237.8	454.8	14.8	922.1	-999.9	-826.8	-863.8
SS	5.73	30.0	110.0	395.	463.	45.0	53.9	17.0	237.3	454.6	15.1	921.9	-999.9	-826.5	-863.4
SS	5.57	31.0	110.0	380.	450.	44.3	53.9	17.0	236.8	454.4	15.3	921.7	-999.9	-826.6	-863.5
SS	5.42	32.0	110.0	366.	438.	43.6	53.8	17.0	236.4	454.1	15.5	921.5	-999.9	-826.7	-863.5
SS	5.29	33.0	110.0	353.	427.	42.8	53.7	17.0	235.9	453.9	15.7	921.3	-999.9	-827.0	-863.8
SS	5.15	34.0	110.0	340.	417.	41.9	53.7	17.0	235.5	453.7	15.9	921.2	-999.9	-827.3	-864.0
SS	5.03	35.0	110.0	328.	407.	41.3	53.6	17.0	235.1	453.5	16.0	921.0	-999.9	-827.4	-864.1
SS	4.92	36.0	110.0	316.	397.	40.6	53.6	17.0	234.7	453.4	16.2	920.9	-999.9	-827.6	-864.2
SS	4.81	37.0	110.0	305.	388.	40.3	53.5	17.0	234.3	453.2	16.3	920.7	-999.9	-827.4	-863.9
SS	4.70	38.0	110.0	295.	380.	40.0	53.5	17.0	233.9	453.0	16.5	920.6	-999.9	-827.3	-863.7
SS	4.61	39.0	110.0	285.	372.	39.5	53.5	17.0	233.5	452.9	16.6	920.5	-999.9	-827.3	-863.7
SS	4.51	40.0	110.0	275.	365.	39.0	53.4	17.0	233.2	452.8	16.7	920.3	-999.9	-827.3	-863.7
SS	4.43	41.0	110.0	266.	358.	37.2	53.4	17.0	232.8	452.6	16.8	920.2	-999.9	-828.7	-865.1
SS	4.34	42.0	110.0	257.	351.	35.3	53.4	17.0	232.5	452.5	16.9	920.1	-999.9	-830.2	-866.6
SS	4.26	43.0	110.0	248.	344.	33.7	53.4	17.0	232.2	452.4	17.0	920.0	-999.9	-831.3	-867.7
SS	4.19	44.0	110.0	240.	338.	32.2	53.4	17.0	231.9	452.3	17.1	919.9	-999.9	-832.5	-868.8

FIGURE 2b: Example sporadic-E mode rayset table. (two hop)

2.2) FOR030: Vertical ionograms

These graphs present the important ionospheric characteristics of each sample area. The characteristics are summarized in a small table in the upper left corner of the plot. In this table the regular layers are summarized with 'FC', the layer critical frequency, 'HC', the height of maximum ionization, and 'YM', the semithickness of the layer. The sporadic-E layer is characterized by its critical frequency distribution; 'L','M', and 'U' are the low, median, and upper deciles, respectively. The plot itself is entirely composed of normal text characters and will print correctly on any common printer. See figure 3 for an example.

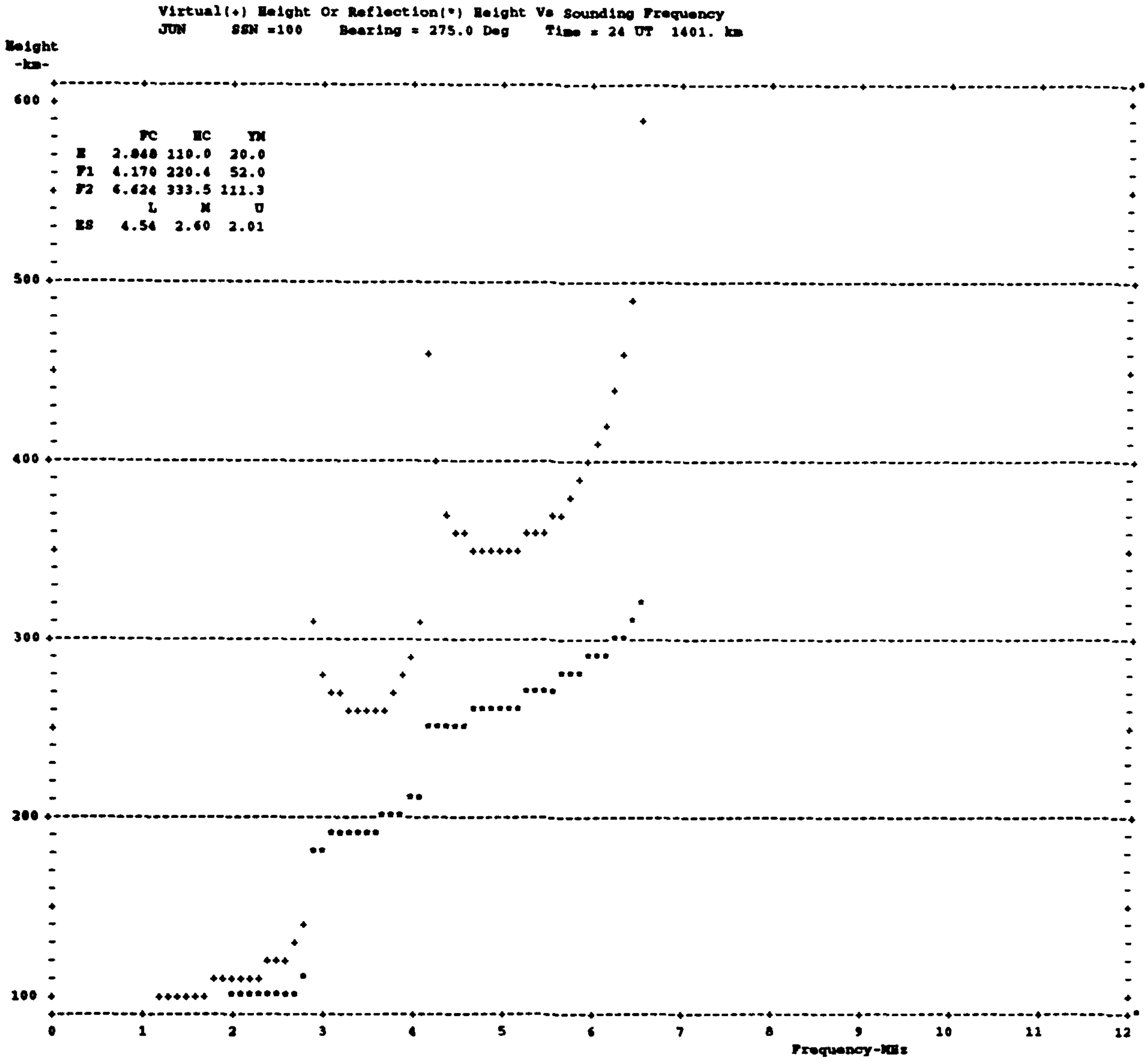


FIGURE 3: Sample vertical ionogram.

2.3) FOR030: Combined frequencies range plot

These graphs present the backscatter return vs. range. They can be generated in signal-to-noise (target return) or clutter-to-noise (sea/ground return) vs. ground or slant range. The symbols composing the filled curve in the figure represent the best frequency according to the key at the bottom of the figure. This figure may be continued for up to three pages if the predicted radar performance demands it. Fortran unit 32 has a nearly identical figure, differing only in that the symbols used represent propagation mode instead of frequency. See figure 4,a,b,c for an example plot.

Range Coverage, Amplitude Vs Time Delay JUN SSN = 100 Time = 24 GMT
Radar Location 51.44 N Lat 79.16 W Lon Bearing = 275.00 Deg
Peak Power = 0.200 MW Pulse Width = 120.00 Microsec
Reff = 0.0 dBW Above Noise Floor

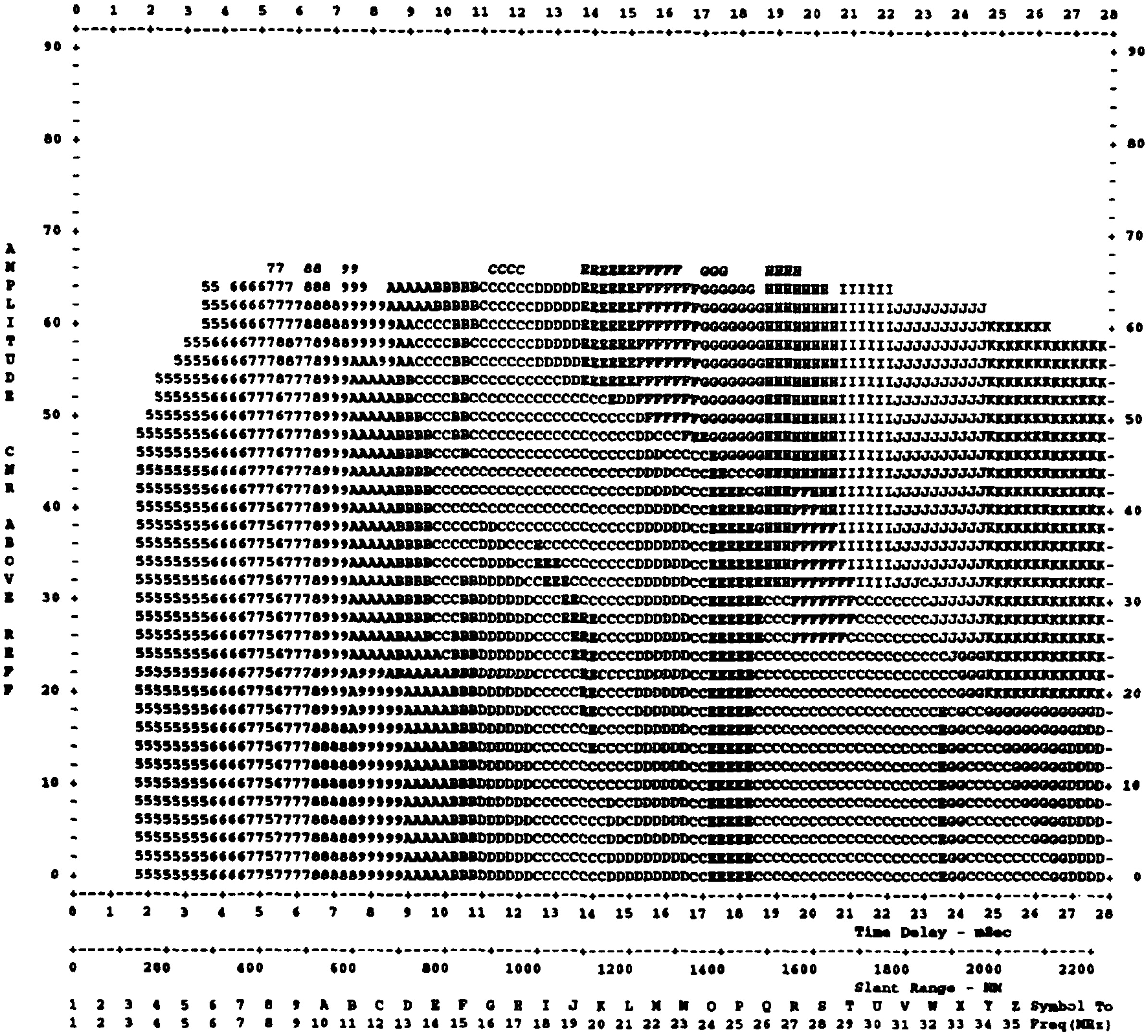


FIGURE 4a: Sample range coverage plot from fortran unit 30

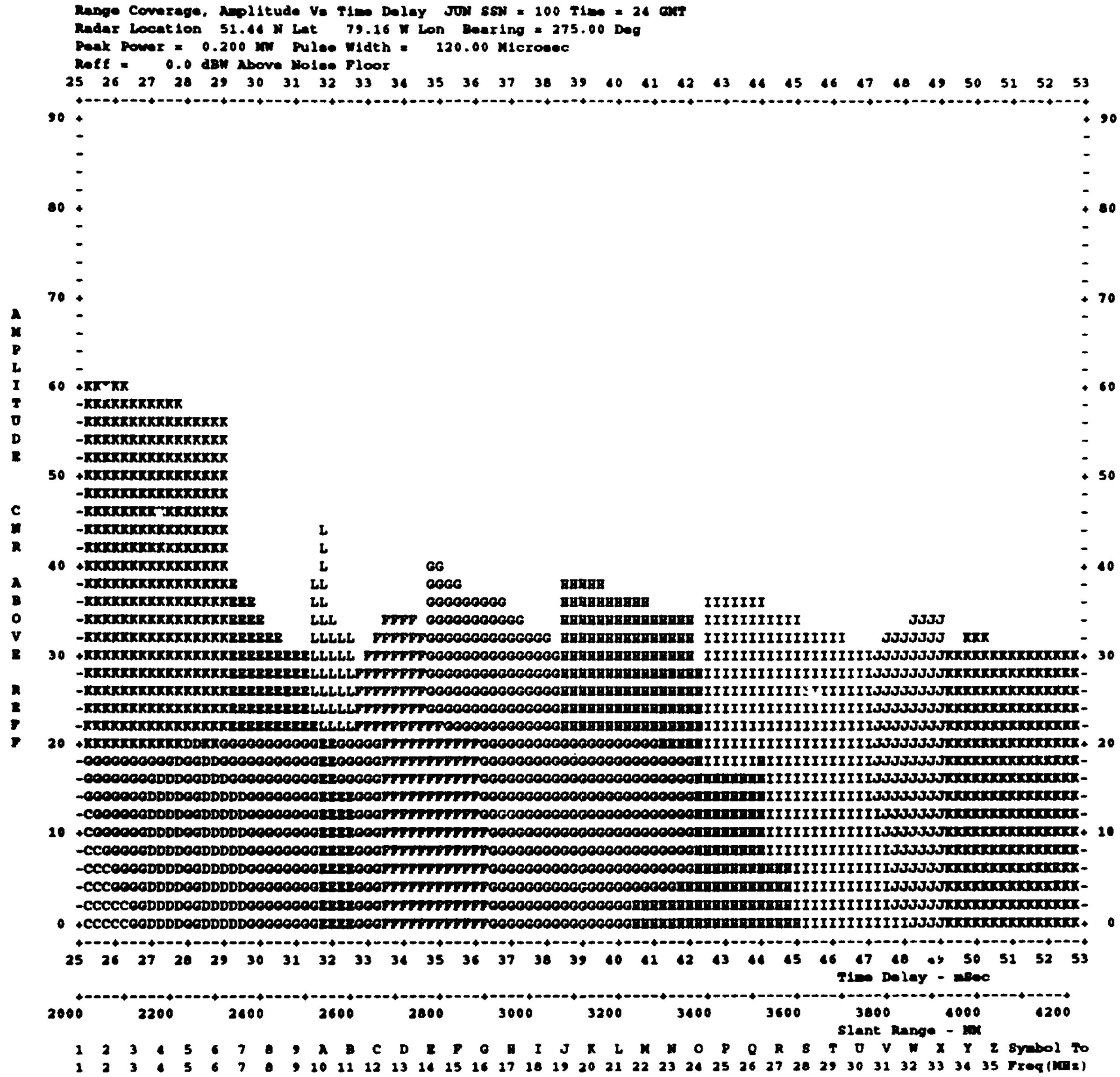


FIGURE 4b: Sample range coverage from unit 30, second page

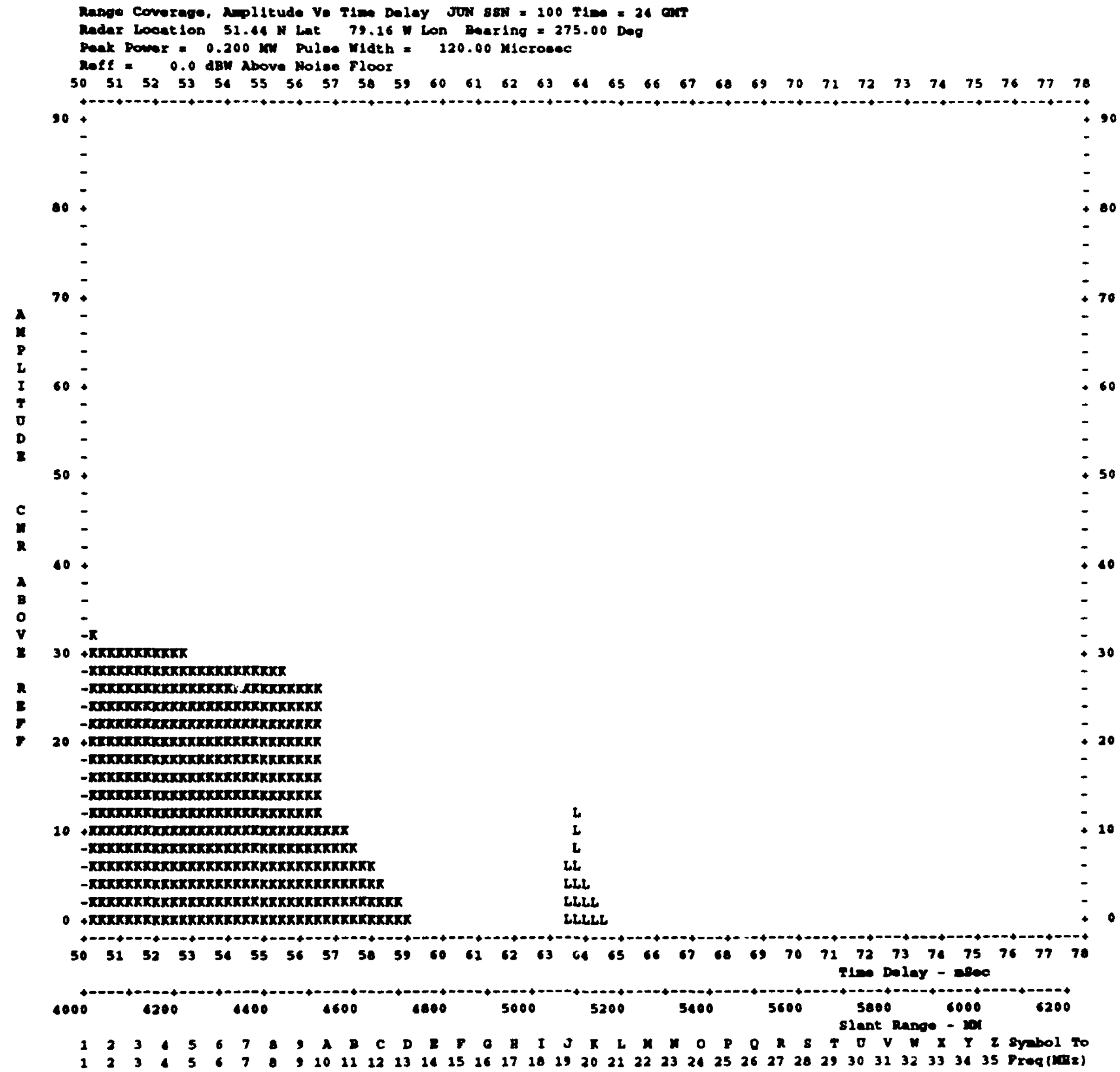


FIGURE 4c: Sample range coverage from unit 30, third page

2.4) FOR030: Oblique ionograms

These graphs present the same variables as the range plot, but in a different form. The ionograms can be generated in signal-to-noise (target return) or clutter-to-noise (sea/ground return). The symbols composing the data in the figure represent the SNR/CNR for each frequency and delay. The data on the bottom line (zero delay) are the noise reference for each frequency. The oblique ionogram is generated at each of two different scales in time delay: 0 to 50 ms in steps of 1 ms (see figure 5) and 0 to 25 ms in steps of .5 ms (see figure 6).

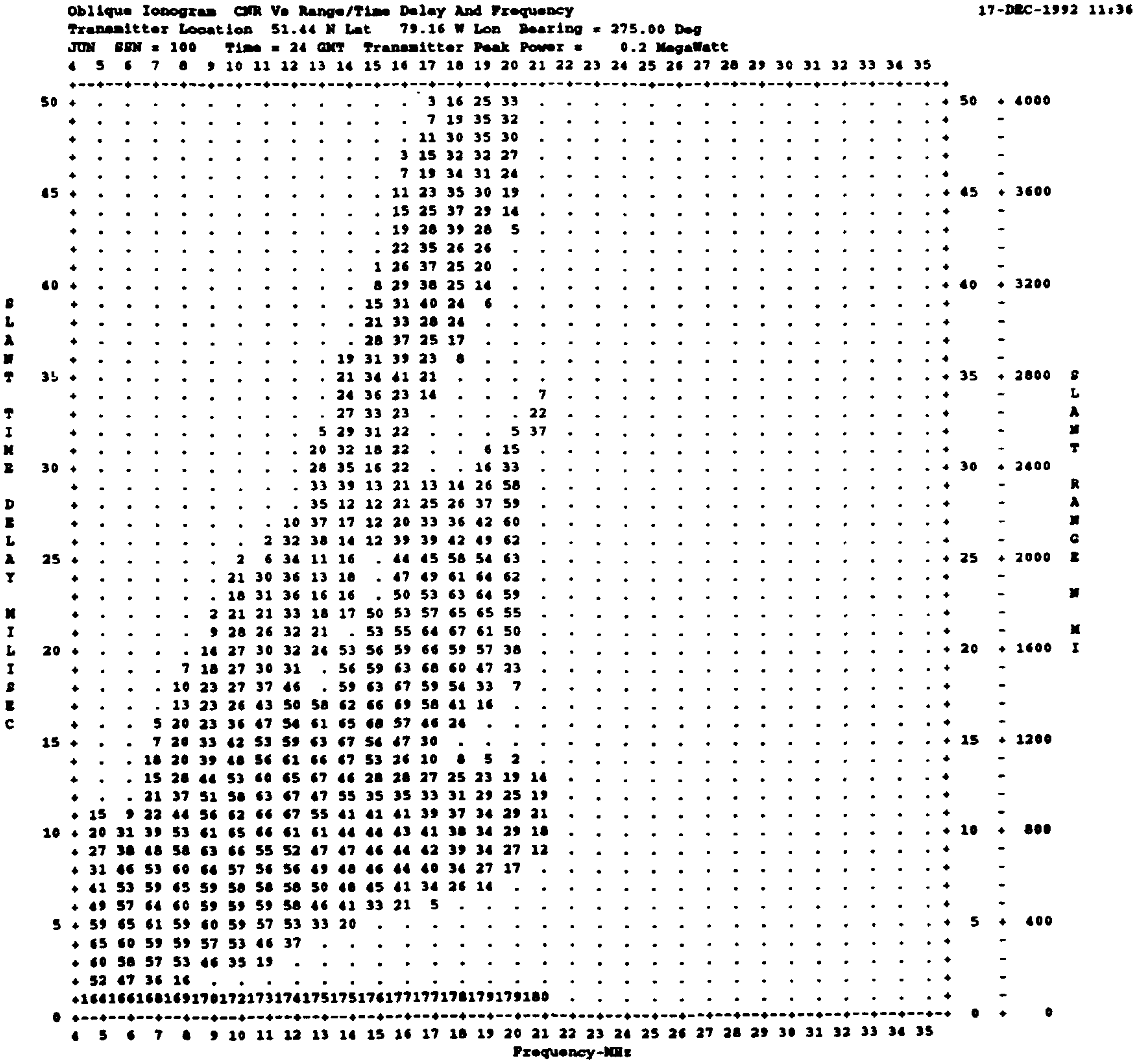


FIGURE 5: Sample oblique ionogram from unit 30, large scale

```
       Oblique Ionogram  CMR Vs Range/Time Delay And Frequency                                   17-DEC-1992 11:36
       Transmitter Location  51.44 N Lat   79.16 W Lon  Bearing = 275.00 Deg
       JUN  SSN = 100   Time = 24 GMT  Transmitter Peak Power =    0.2 MegaWatt
         4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
       +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
       +  .  .  .  .  .  .  2  6 34 11 16  . 44 45 58 54 63  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      + 2000
       +  .  .  .  .  .  . 22 29 35 13 17  . 45 47 60 64 62  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
    24 +  .  .  .  .  .  . 21 30 36 13 18  . 47 49 61 64 62  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 24   -
       +  .  .  .  .  .  . 19 31 36 14 19  . 48 52 62 64 61  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       +  .  .  .  .  .  . 18 31 36 16 16  . 50 53 63 64 59  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       +  .  .  .  .  .  . 16 32 33 17 16  . 52 56 64 64 58  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      + 1800
    22 +  .  .  .  .  .  2 21 21 33 18 17 50 53 57 65 65 55  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 22   -
       +  .  .  .  .  .  4 24 23 32 20  . 52 55 59 66 65 52  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       +  .  .  .  .  .  9 28 26 32 21  . 53 55 64 67 61 50  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       +  .  .  .  .  . 11 28 28 32 22 51 54 58 65 59 59 42  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
    20 +  .  .  .  .  . 14 27 30 32 24 53 56 59 66 59 57 38  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 20   + 1600
S      +  .  .  .  .  5 19 27 30 31 13 54 58 62 67 59 51 33  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
L      +  .  .  .  .  7 18 27 30 31  . 56 59 63 68 60 47 23  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
A      +  .  .  .  .  9 24 27 30 31  . 57 62 65 60 60 43 12  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
N   18 +  .  .  .  . 10 23 27 37 46  . 59 63 67 59 54 33  7  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 18   -
T      +  .  .  .  . 11 22 26 41 49 55 60 64 68 58 45 22  1  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      + 1400  S
       +  .  .  .  . 13 23 26 43 50 58 62 66 69 58 41 16  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       L
T      +  .  .  .  3 15 24 31 46 53 60 63 67 59 50 36 10  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       A
I   16 +  .  .  .  5 20 23 36 47 54 61 65 68 57 46 24  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 16   -       N
M      +  .  .  .  8 19 28 39 48 56 62 66 68 56 41 12  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       T
E      +  .  .  .  7 20 33 42 53 59 63 67 54 47 30  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      + 1200
       +  .  . 10 20 35 46 54 60 65 68 53 37 18  5  2  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       R
D   14 +  .  . 18 20 39 48 56 61 66 67 53 26 10  8  5  2  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 14   -       A
E      +  .  . 16 25 41 50 58 63 66 45 45 19 18 17 14 11  6  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       N
L      +  .  . 15 28 44 53 60 65 67 46 28 28 27 25 23 19 14  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       G
A      +  .  . 15 35 47 55 62 67 67 49 30 30 29 27 25 21 16  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      + 1000  E
Y   12 +  .  . 21 37 51 58 63 67 47 55 35 35 33 31 29 25 19  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 12   -
       +  . 11 17 40 53 61 65 67 54 37 37 37 35 33 30 26 19  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       K
M      + 15  9 22 44 56 62 66 67 55 41 41 41 39 37 34 29 21  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
I      + 16 14 26 48 58 65 67 60 59 42 42 41 40 37 34 29 20  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -       M
L   10 + 20 31 39 53 61 65 66 61 61 44 44 43 41 38 34 29 18  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . + 10   +  800  I
I      + 22 32 46 55 62 65 65 63 46 45 44 43 41 38 34 29 16  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
S      + 27 38 48 58 63 66 55 52 47 47 46 44 42 39 34 27 12  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
E      + 29 43 51 59 64 65 56 55 48 48 46 44 41 36 30 21  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
C    8 + 31 46 53 60 64 57 56 56 49 48 46 44 40 34 27 17  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +  8   -
       + 37 49 57 63 67 58 56 57 49 48 46 43 38 32 24 12  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      +  600
       + 41 53 59 65 59 58 58 58 50 48 45 41 34 26 14  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       + 45 55 63 68 60 58 59 59 50 47 43 37 28 16  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
     6 + 49 57 64 60 59 59 59 58 46 41 33 21  5  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +  6   -
       + 53 61 68 60 59 60 59 57 43 36 25  9  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       + 59 65 61 59 60 59 57 53 33 20  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      +  400
       + 62 67 59 60 59 57 52 46 16  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
     4 + 65 60 59 59 57 53 46 37  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +  4   -
       + 66 58 58 57 52 44 32 15  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       + 60 58 57 53 46 35 19  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       + 57 55 50 41 27  5  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      +  200
     2 + 52 47 36 16  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +  2   -
       +  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       +  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
       +164166168169170172173174175175176177177178179179180  .  .  .  .  .  .  .  .  .  .  .  .  .  .  . +      -
     0 +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+  0   +    0
         4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
                                               Frequency-MHz
```

FIGURE 6: Sample oblique ionogram from unit 30, small scale

2.5) FOR030: Combined mode/frequency rayset tables

This table presents the same information as the rayset tables in fortran unit 10. However, all frequencies and modes for which unit 10 raysets were generated are represented. The sorting algorithm is somewhat similar to the one used in the 'allmodes.dat' output. The important difference is that this table contains no interpolated values; certain apparent inconsistencies are possible. The intent behind the table is to organize only those raysets which contribute to the top of the envelope in the backscatter vs. range plots. The inconsistency arises when the mode/frequency providing the strongest returns is changing rapidly in distance for small changes in elevation; change on the order of 100 km/degree is sufficient. When this rapid change occurs, a weaker return from another mode/frequency may be inserted into the table at the skipped-over range. The intent behind 'allmodes.dat' is to avoid this problem by filling every range bin with the appropriate value, occasionally using interpolation to achieve that end. See figure 7 for an example. Note that this table was truncated at a slant range near 2600 NM, normally the table would continue to the longest slant range shown in the range coverage plots.

JUN SSN = 100 TIME = 24 GMT 17-DEC-1992 11:36
RADAR LOCATION 51.44 N LAT 79.16 W LON BEARING = 275.00 DEG
PEAK POWER = 0.200 MW PULSE WIDTH = 120.00 MICROSEC
AVERAGE/PEAK PWR RATIO = 0.0 DB OTH PATH ENHANCEMENT = 6.0 DB
INTEGRATION TIME = 3.10 SEC (OR 4.9 DB)

S-RNG KM	FREQ MHZ	TIME MSEC	ELANG DEG	HITE KM	GT+GR DB	C-AREA DBSM	T-AREA DBSM	R4TH DBM	ABS DB	DEV DB	OBP DB	REF DB	G-LOS DB	T-LOSS DB	P-REC DBW	CNR DB	SNR DB	NOISE DBW	
318	5.0	3.9	22.0	116	44.4	56.2	17.0	230.8	22.2	6.7	0.0	0.0	0.0	35.4	-99.1	65.9	26.7	-160.1	E
326	5.0	4.0	21.0	114	44.8	56.3	17.0	231.3	23.0	6.4	0.0	0.0	0.0	35.9	-99.6	65.4	26.2	-160.1	E
393	6.0	4.9	17.0	116	47.2	56.1	17.0	234.5	21.4	6.3	0.0	0.0	0.0	34.2	-100.4	66.6	27.4	-162.1	E
457	7.0	5.7	15.0	122	48.7	56.1	17.0	237.1	18.9	7.2	0.0	0.0	0.0	32.6	-101.3	67.4	28.3	-163.8	E
481	7.0	6.0	13.0	115	48.4	56.3	17.0	238.0	20.7	5.8	0.0	0.0	0.0	33.0	-102.7	66.0	26.7	-163.8	E
538	8.0	6.7	12.0	122	49.9	56.2	17.0	240.0	17.9	6.7	0.0	0.0	0.0	31.1	-102.6	67.6	28.4	-165.3	E
577	8.0	7.2	10.0	114	49.2	56.4	17.0	241.2	19.7	5.4	0.0	0.0	0.0	31.6	-104.7	65.5	26.1	-165.3	E
637	9.0	7.9	9.0	118	49.8	56.4	17.0	242.9	17.3	6.0	0.0	0.0	0.0	29.8	-105.0	66.5	27.1	-166.6	E
681	9.0	8.4	28.0	320	44.9	57.2	17.0	244.1	8.2	9.2	2.9	0.0	0.0	26.8	-107.4	64.1	24.0	-166.6	2
746	10.0	9.2	7.0	120	49.2	56.6	17.0	245.6	16.2	5.8	0.0	0.0	0.0	28.5	-107.9	64.8	25.2	-167.7	E
785	10.0	9.7	6.0	116	48.1	56.8	17.0	246.5	16.9	5.1	0.0	0.0	0.0	28.5	-109.6	63.0	23.3	-167.7	E
849	10.0	10.5	20.0	310	51.6	57.4	17.0	247.9	9.0	8.4	4.9	0.0	0.0	28.8	-107.1	65.5	25.1	-167.7	2
876	11.0	10.9	20.0	321	51.4	57.0	17.0	248.4	7.8	8.1	3.6	0.0	0.0	26.0	-106.4	67.3	27.3	-168.8	2
959	12.0	11.9	18.0	328	52.4	57.0	17.0	250.0	7.3	7.8	3.5	0.0	0.0	25.1	-106.7	67.9	27.9	-169.7	2
983	12.0	12.2	17.0	323	53.1	57.1	17.0	250.4	7.6	7.7	4.0	0.0	0.0	25.8	-107.1	67.6	27.5	-169.7	2
1044	12.0	12.9	15.0	316	54.3	57.3	17.0	251.5	8.3	7.3	5.2	0.0	0.0	27.3	-108.2	66.4	26.1	-169.7	2
1080	13.0	13.4	18.0	377	49.9	57.2	17.0	252.0	9.8	3.4	1.8	0.0	0.0	21.5	-108.2	67.3	27.1	-170.6	2
1148	13.0	14.2	16.0	371	51.4	57.4	17.0	253.1	10.7	3.4	2.7	0.0	0.0	23.3	-109.3	66.2	25.8	-170.6	2
1181	14.0	14.6	16.0	384	51.8	57.3	17.0	253.6	9.4	3.3	1.9	0.0	0.0	21.2	-108.0	68.3	28.0	-171.4	2
1253	14.0	15.5	14.0	376	53.0	57.6	17.0	254.6	10.3	3.1	2.9	0.0	0.0	22.9	-109.4	67.0	26.4	-171.4	2
1300	15.0	16.1	14.0	393	53.6	57.3	17.0	255.3	9.2	3.3	2.1	0.0	0.0	21.0	-108.4	68.7	28.4	-172.2	2
1330	15.0	16.5	13.0	385	53.7	57.4	17.0	255.7	9.6	3.0	2.6	0.0	0.0	21.8	-109.4	67.8	27.3	-172.2	2
1407	16.0	17.4	13.0	414	54.3	57.7	17.0	256.6	8.6	3.6	1.9	0.0	0.0	20.6	-108.8	69.0	28.3	-172.9	2
1429	16.0	17.7	12.0	401	54.5	57.7	17.0	256.9	9.0	3.2	2.4	0.0	0.0	21.1	-109.4	68.4	27.7	-172.9	2
1513	16.0	18.7	10.0	386	54.2	57.9	17.0	257.9	9.9	2.9	3.7	0.0	0.0	23.0	-112.3	65.5	24.6	-172.9	2
1557	17.0	19.3	11.0	425	54.9	58.1	17.0	258.4	8.5	3.6	2.2	0.0	0.0	20.8	-110.4	68.1	27.0	-173.6	2
1576	17.0	19.5	10.0	408	54.8	58.1	17.0	258.6	8.9	3.2	2.8	0.0	0.0	21.4	-111.2	67.3	26.1	-173.6	2
1647	16.0	20.4	8.0	384	52.3	58.3	17.0	259.4	10.9	2.9	5.3	0.0	0.0	25.6	-117.9	59.9	18.6	-172.9	2
1678	17.0	20.8	8.0	394	53.0	58.4	17.0	259.7	9.8	2.8	4.3	0.0	0.0	23.3	-115.8	62.7	21.3	-173.6	2
1725	18.0	21.4	9.0	436	54.5	58.5	17.0	260.2	8.5	3.6	2.7	0.0	0.0	21.3	-113.1	66.1	24.6	-174.2	2
1801	18.0	22.3	7.0	409	52.4	58.7	17.0	260.9	9.3	2.9	4.1	0.0	0.0	22.8	-117.3	61.8	20.2	-174.2	2
1865	18.0	23.1	6.0	403	51.1	58.8	17.0	261.5	9.7	2.7	4.8	0.0	0.0	23.7	-120.0	59.1	17.3	-174.2	2
1910	17.0	23.6	5.0	389	47.9	58.9	17.0	262.0	11.2	2.7	6.6	0.0	0.0	27.1	-126.4	52.1	10.2	-173.6	2
1927	19.0	23.9	7.0	452	53.0	58.9	17.0	262.1	8.5	3.7	3.3	0.0	0.0	21.9	-117.1	62.6	20.7	-174.8	2
2017	19.0	25.0	5.0	424	48.7	59.1	17.0	262.9	9.2	3.0	4.6	0.0	0.0	23.3	-123.4	56.3	14.2	-174.8	2
2027	18.0	25.1	4.0	396	45.5	59.1	17.0	263.0	10.5	2.6	6.2	0.0	0.0	25.8	-128.8	50.3	8.2	-174.2	2
2090	19.0	25.9	4.0	416	45.7	59.3	17.0	263.5	9.5	.2.8	5.2	0.0	0.0	24.0	-127.7	52.0	9.8	-174.8	2
2167	13.0	26.8	19.0	394	49.2	60.3	17.0	264.1	22.3	8.8	2.5	0.0	0.5	40.6	-137.1	38.5	-4.8	-170.6	2
2189	20.0	27.1	5.0	482	49.1	59.5	17.0	264.3	8.4	4.0	3.8	0.0	0.0	22.7	-123.9	56.4	13.9	-175.4	2
2228	20.0	27.6	4.0	462	45.8	59.6	17.0	264.6	8.7	3.6	4.3	0.0	0.0	23.1	-127.9	52.4	9.9	-175.4	2
2294	20.0	28.4	3.0	451	39.8	59.7	17.0	265.1	9.0	3.3	4.8	0.0	0.0	23.6	-134.8	45.5	2.8	-175.4	2
2371	14.0	29.4	17.0	403	51.0	60.4	17.0	265.7	21.4	8.6	2.6	0.0	0.6	39.6	-136.4	39.9	-3.5	-171.4	2
2423	14.0	30.0	16.0	396	51.8	60.5	17.0	266.1	22.3	8.4	3.4	0.0	0.6	41.2	-137.4	39.0	-4.5	-171.4	2
2434	20.0	30.1	2.0	462	33.8	59.9	17.0	266.2	12.4	4.1	5.7	0.0	0.0	28.8	-146.7	33.6	-9.4	-175.4	2
2499	14.0	30.9	15.0	393	52.4	60.6	17.0	266.6	23.3	8.2	4.4	0.0	9.9	52.3	-148.4	28.0	-15.6	-171.4	2

FIGURE 7: Sample combined frequency/modes table.

2.6) FOR032: Single frequency range plots

These graphs present the backscatter return vs. range for each frequency. They can be generated in signal-to-noise (target return) or clutter-to-noise (sea/ground return) vs. ground or slant range. The symbols composing the filled curve in the figure represent the mode with the highest SNR/CNR according to the key at the bottom of the figure. This figure may be continued for up to three pages if the predicted radar performance demands it (See figure 8a,b). Fortran unit 30 has a similar figure, differing only in that all frequencies run are included, and the symbols used represent frequency instead of propagation mode.

Range Coverage, Amplitude Vs Time Delay JUN SSN = 100 Time = 24 GMT Frequency = 13.000 MHz 17-DEC-1992 11:36
Radar Location 51.44 N Lat 79.16 W Lon Bearing = 275.00 Deg ANTTYP 12
Peak Power = 0.200 Megawatt Pulse Width = 120.00 microsec
Reff = 0.0 dB Above Noise Level Of -175.5 dBW

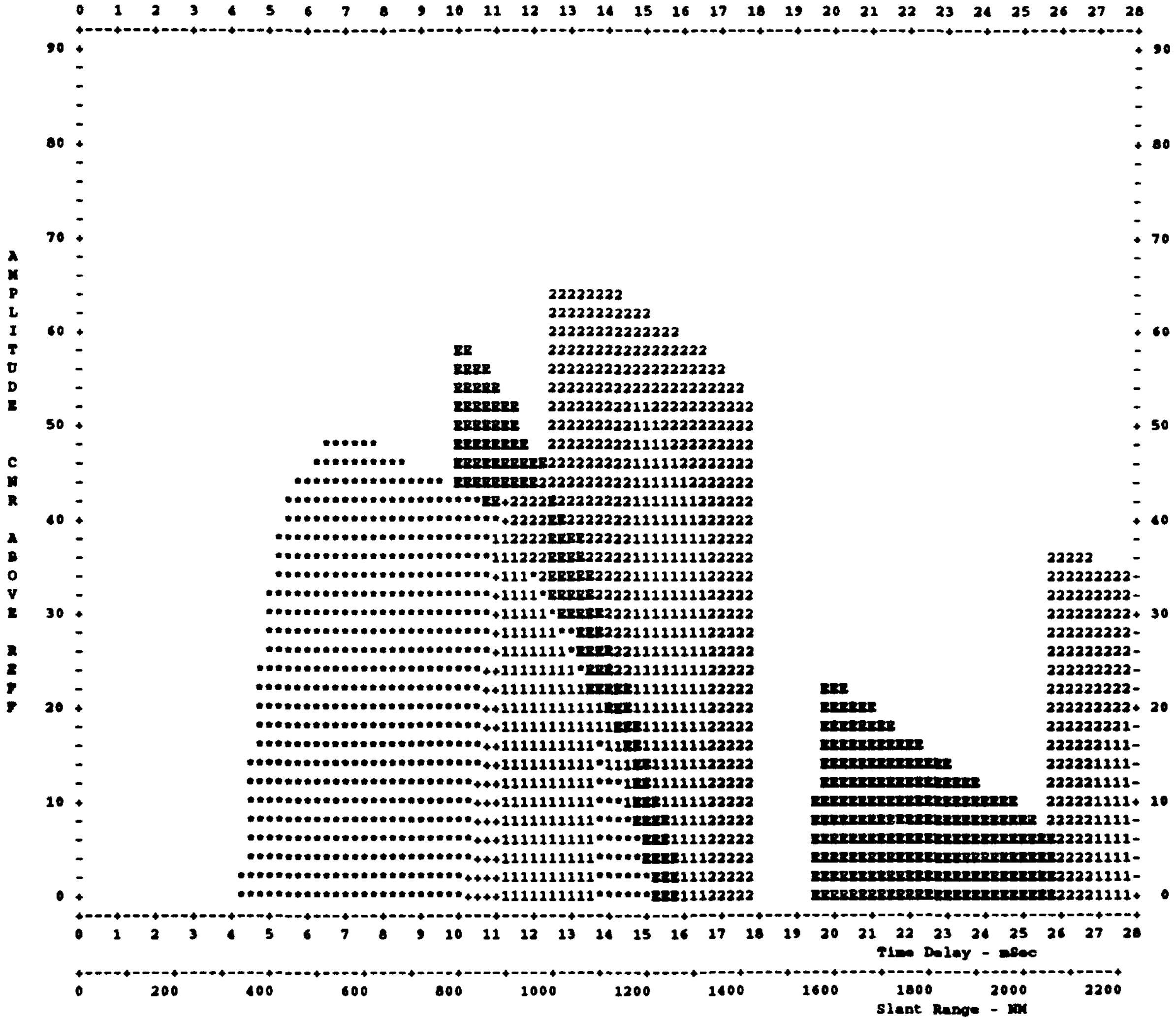


FIGURE 8a: Single frequency range coverage from unit 32 (first page)

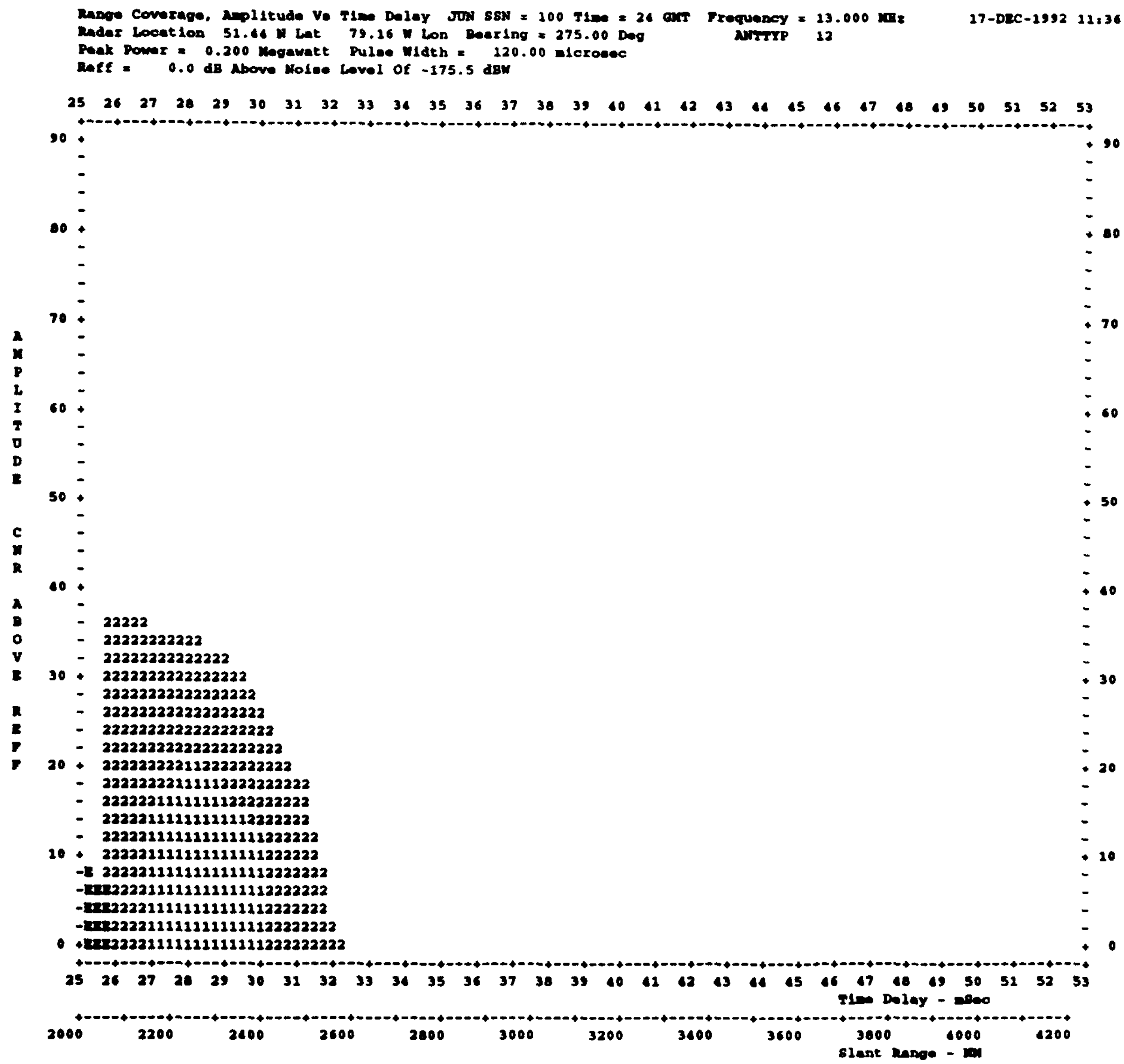


FIGURE 8b: Single frequency range coverage from unit 32 (second page)

2.7) FOR032: Single frequency angle coverage

These graphs present the rayset geometry in a different form. The mode is plotted as a function of elevation angle and time delay. The leftmost curve for each mode is the one-hop; the hop increases by one for each curve per mode, read left-to-right. The mode symbols are '*','1','2', and '+' for the sporadic-E, F_1, F_2, and over-the-MUF modes, respectively. The figure may be continued up to three pages if necesssary (See figure 9a,b).

Angle Coverage, Amplitude Vs Time Delay JUN SSN = 100 Time = 24 GMT Frequency = 13.000 MHz 17-DEC-1992 11:36
Radar Location 51.44 N Lat 79.16 W Lon Bearing = 275.00 Deg ANTTYP 12
Peak Power = 0.200 Megawatt Pulse Width = 120.00 microsec
Reff = 0.0 dB Above Noise Level Of -175.5 dBW

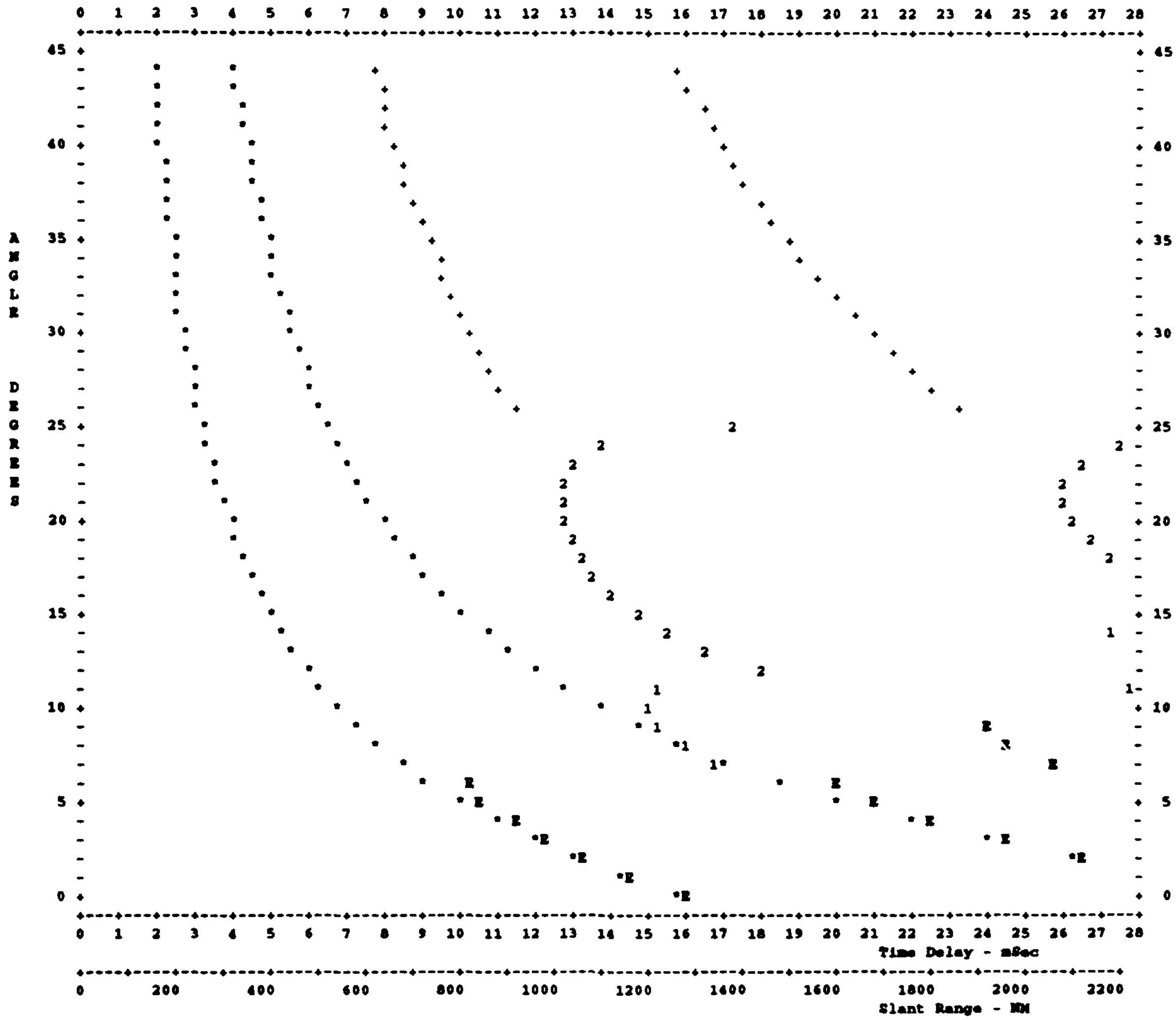


FIGURE 9a: Sample single frequency angle coverage from unit 32

Angle Coverage, Amplitude Vs Time Delay JUN SSN = 100 Time = 24 GMT Frequency = 13.000 MHz 17-DEC-1992 11:36
Radar Location 51.44 N Lat 79.16 W Lon Bearing = 275.00 Deg ANTTYP 12
Peak Power = 0.200 Megawatt Pulse Width = 120.00 microsec
Reff = 0.0 dB Above Noise Level Of -175.5 dBW

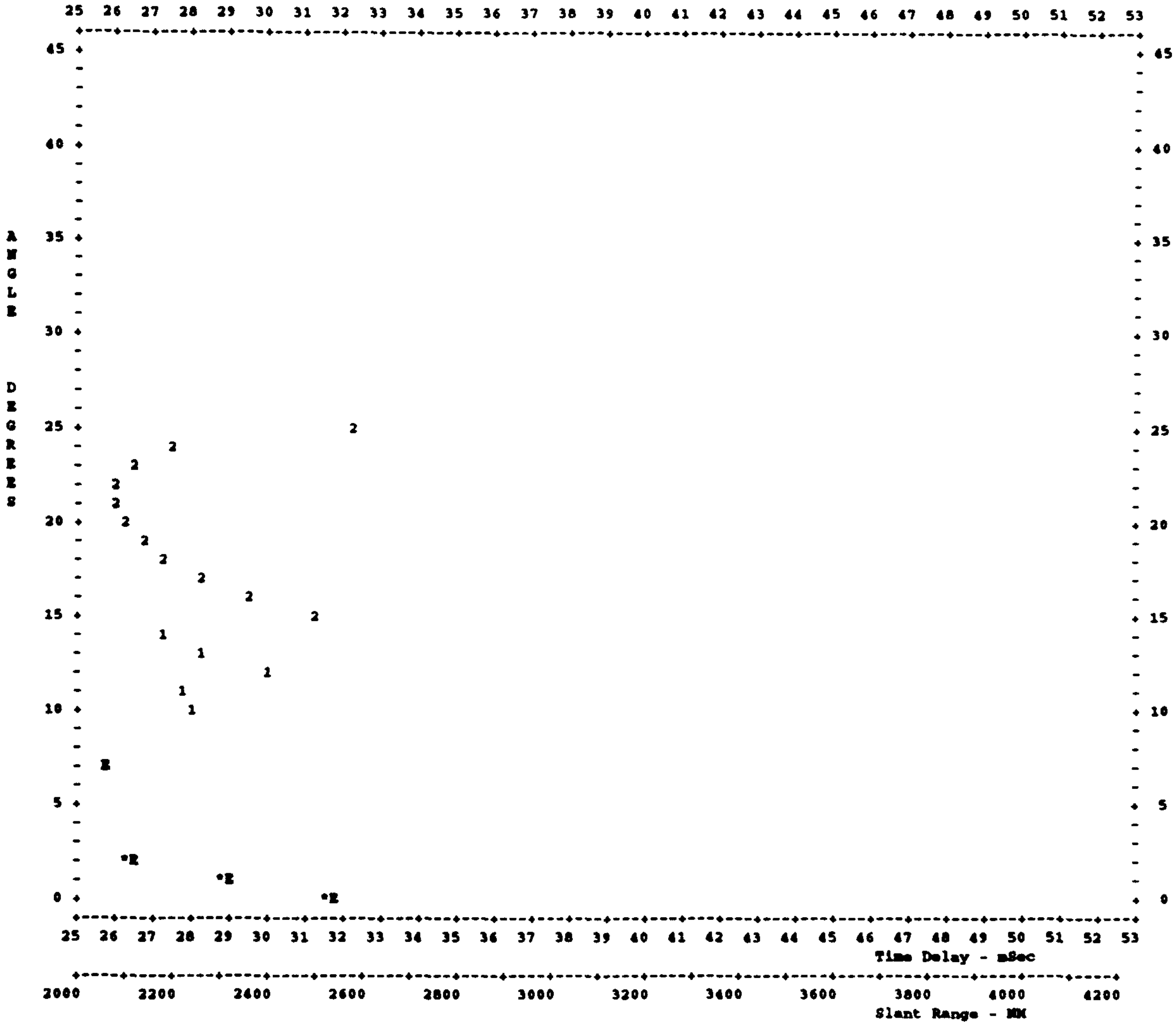


FIGURE 9b: Sample single frequency angle coverage from unit 32

2.8) ALLMODES.DAT: Combined envelope rayset tables

This table presents the same information as the rayset tables in fortran unit 10 and the combined raysets of fortran unit 30. However, all frequencies and modes for which unit 10 raysets were generated are represented, and, although the sorting algorithm is somewhat similar to the one used in the fortran unit 30 output, this table contains interpolated values. The sorting algorithm traces the envelope of each mode, rather than the discrete raysets. Values of the interpolated envelope then fill range bins that would otherwise fall through to a weaker return. The intent behind the table is to organize only those raysets which contribute to the top of the envelope in the backscatter vs. range plots. The match is good even when the mode/frequency providing the strongest returns is changing rapidly in distance for small changes in elevation. When this rapid change occurs, a weaker return from another mode/frequency will be covered by the envelope of the strongest return. The items in the table are similar to the fortran unit 10 items, with two exceptions. The column labelled 'NOISE' does not appear in fortran unit 10 rayset tables because the noise reference is constant for constant frequencies. This table may have different frequencies, hence the need for a noise reference in the body of the table. In the last column (unlabelled to save space) is a mode symbol. This is identical to the mode symbols in the fortran unit 10 raysets, except when the rayset has been calculated by interpolation of the envelope. In this case the mode symbol will be ' - '. All raysets not marked as interpolated are actual, calculated raysets that match raysets in fortran unit 10. See figure 10 for an example.

JUN SSN = 100 TIME = 24 GMT 17-DEC-1992 11:36
RADAR LOCATION 51.44 N LAT 79.16 W LON BEARING = 275.00 DEG
PEAK POWER = 0.200 MW PULSE WIDTH = 120.00 MICROSEC
AVERAGE/PEAK PWR RATIO = 0.0 DB OTH PATH ENHANCEMENT = 6.0 DB
INTEGRATION TIME = 3.10 SEC (OR 4.9 DB)

S-RNG NM	FREQ MHZ	TIME MSEC	ELANG DEG	HITE KM	GT+GR DB	CAREA DBSM	TAREA DBSM	R4TH DBM	ABS DB	DEV DB	OBF DB	REF DB	G-LOS DB	T-LOSS DB	P-REC DBW	CNR DB	SNR DB	NOISE DBW	
290.	5.0	3.59	23.0	110.	44.2	55.8	17.0	229.2	0.0	0.0	0.0	41.9	0.0	41.9	-109.5	60.4	21.6	-165.0	S
313.	5.0	3.87	23.0	119.	44.2	56.1	17.0	230.5	21.4	7.5	0.0	0.0	0.0	35.4	-99.1	65.9	26.8	-160.1	E
383.	6.0	4.74	18.0	119.	47.2	56.0	17.0	234.0	20.5	7.1	0.0	0.0	0.0	34.1	-100.0	67.0	28.0	-162.1	E
406.	6.0	5.03	16.0	114.	47.2	56.3	17.0	235.1	22.3	5.9	0.0	0.0	0.0	34.7	-101.4	65.6	26.4	-162.1	E
457.	7.0	5.66	15.0	123.	48.7	56.1	17.0	237.1	18.9	7.2	0.0	0.0	0.0	32.6	-101.3	67.4	28.3	-163.8	E
539.	8.0	6.67	12.0	122.	49.9	56.2	17.0	240.0	17.9	6.7	0.0	0.0	0.0	31.1	-102.6	67.6	28.4	-165.3	E
552.	8.0	6.83	11.0	117.	49.6	56.2	17.0	240.4	18.8	5.8	0.0	0.0	0.0	31.1	-103.2	67.0	27.7	-165.3	E
637.	9.0	7.89	9.0	119.	49.8	56.4	17.0	242.9	17.3	6.0	0.0	0.0	0.0	29.8	-105.0	66.5	27.1	-166.6	E
670.	9.0	8.30	8.0	116.	49.2	56.6	17.0	243.8	18.2	5.3	0.0	0.0	0.0	29.9	-106.5	65.0	25.4	-166.6	E
722.	10.0	8.93	29.0	350.	45.9	57.0	17.0	245.0	6.7	10.5	1.6	0.0	0.0	25.4	-107.0	65.6	25.6	-167.7	2
786.	10.0	9.73	23.0	319.	48.3	57.1	17.0	246.5	8.1	8.3	3.5	0.0	0.0	26.4	-107.0	65.7	25.6	-167.7	2
842.	11.0	10.42	22.0	332.	49.4	56.9	17.0	247.7	7.2	8.6	2.8	0.0	0.0	25.2	-106.9	66.8	26.9	-168.8	2
858.	11.0	10.62	21.0	327.	50.4	57.0	17.0	248.0	7.5	8.2	3.2	0.0	0.0	25.4	-106.4	67.3	27.3	-168.8	2
939.	12.0	11.63	19.0	335.	51.8	57.0	17.0	249.6	7.0	8.2	3.1	0.0	0.0	24.8	-106.8	67.9	27.9	-169.7	2
960.	12.0	11.88	18.0	329.	52.4	57.0	17.0	250.0	7.3	7.8	3.5	0.0	0.0	25.1	-106.7	67.9	27.9	-169.7	2
1045.	13.0	12.93	20.0	393.	48.6	57.1	17.0	251.5	9.1	3.9	1.1	0.0	0.0	20.6	-108.2	67.3	27.2	-170.6	2
1060.	13.0	13.12	19.0	384.	49.2	57.1	17.0	251.7	9.5	3.6	1.4	0.0	0.0	21.0	-108.1	67.4	27.3	-170.6	2
1110.	13.0	13.73	17.0	373.	50.7	57.3	17.0	252.5	10.3	3.3	2.2	0.0	0.0	22.2	-108.6	67.0	26.7	-170.6	2
1162.	14.0	14.38	17.0	394.	51.0	57.3	17.0	253.3	9.1	3.5	1.5	0.0	0.0	20.6	-108.0	68.3	28.0	-171.4	2
1213.	14.0	15.01	15.0	379.	52.4	57.4	17.0	254.1	9.9	3.2	2.3	0.0	0.0	21.9	-108.5	67.8	27.4	-171.4	2
1278.	15.0	15.82	15.0	404.	52.9	57.3	17.0	255.0	8.8	3.6	1.6	0.0	0.0	20.5	-108.3	68.8	28.5	-172.2	2
1300.	15.0	16.09	14.0	394.	53.6	57.3	17.0	255.3	9.2	3.3	2.1	0.0	0.0	21.0	-108.4	68.7	28.4	-172.2	2
1375.	15.0	17.01	12.0	381.	53.8	57.5	17.0	256.2	10.1	3.0	3.2	0.0	0.0	22.8	-110.7	66.4	25.9	-172.2	2
1403.	16.0	17.37	14.0	433.	54.2	57.7	17.0	256.6	8.2	4.2	1.4	0.0	0.0	20.3	-108.7	69.1	28.4	-172.9	2
1467.	16.0	18.15	11.0	393.	54.4	57.8	17.0	257.4	9.4	2.9	3.0	0.0	0.0	21.9	-110.7	67.1	26.3	-172.9	2
1514.	16.0	18.73	10.0	387.	54.2	57.9	17.0	257.9	9.9	2.9	3.7	0.0	0.0	23.0	-112.3	65.5	24.6	-172.9	2
1553.	17.0	19.22	12.0	447.	54.9	58.1	17.0	258.4	8.1	4.2	1.7	0.0	0.0	20.5	-110.0	68.5	27.4	-173.6	2
1600.	17.0	19.80	13.1	491.	54.5	58.2	17.0	258.9	7.7	5.6	1.3	0.0	0.0	21.1	-111.3	67.2	26.0	-178.5	-
1650.	17.0	20.42	13.5	520.	54.4	58.4	17.0	259.4	7.6	6.7	1.2	0.0	0.0	22.0	-112.7	65.8	24.5	-178.5	-
1719.	18.0	21.28	10.0	460.	55.4	58.5	17.0	260.1	8.1	4.2	2.1	0.0	0.0	20.9	-111.8	67.4	25.9	-174.2	2
1767.	18.0	21.86	11.0	504.	55.4	58.6	17.0	260.6	7.7	5.5	1.6	0.0	0.0	21.4	-112.6	66.5	24.9	-174.2	2
1800.	18.0	22.28	11.1	520.	55.4	58.7	17.0	260.9	7.7	6.3	1.6	0.0	0.0	22.1	-113.6	65.6	23.9	-179.1	-
1850.	18.0	22.90	11.3	545.	55.3	58.8	17.0	261.3	7.6	7.5	1.5	0.0	0.0	23.2	-115.0	64.1	22.3	-179.1	-
1925.	19.0	23.82	8.0	481.	54.3	58.9	17.0	262.1	8.1	4.3	2.6	0.0	0.0	21.5	-115.4	64.3	22.3	-174.8	2
1984.	19.0	24.56	9.0	532.	55.2	59.1	17.0	262.6	7.7	5.9	2.1	0.0	0.0	22.2	-115.6	64.1	22.0	-174.8	2
2021.	20.0	25.01	8.0	516.	54.9	59.2	17.0	262.9	7.4	8.8	0.0	0.0	0.0	22.7	-117.1	63.2	21.1	-175.4	+
2070.	18.0	25.61	12.0	655.	55.3	59.3	17.0	263.3	7.3	12.9	1.2	0.0	0.0	27.9	-1 1.3	57.9	15.5	-174.2	2
2100.	19.0	25.99	3.9	416.	45.0	59.3	17.0	263.6	9.6	2.8	5.3	0.0	0.0	24.1	-128.5	51.2	8.9	-179.7	-
2191.	20.0	27.12	6.0	516.	52.4	59.5	17.0	264.3	8.1	4.9	3.2	0.0	0.0	22.7	-120.6	59.7	17.2	-175.4	2
2200.	20.0	27.23	6.1	521.	52.5	59.5	17.0	264.4	8.0	5.1	3.1	0.0	0.0	22.8	-120.7	59.6	17.1	-180.3	-
2250.	20.0	27.85	6.4	551.	52.9	59.6	17.0	264.8	7.9	5.9	2.9	0.0	0.0	23.3	-121.1	59.2	16.6	-180.3	-
2343.	20.0	29.00	7.0	607.	53.7	59.8	17.0	265.5	7.7	7.5	2.6	0.0	0.0	24.3	-121.8	58.4	15.6	-175.4	2
2350.	20.0	29.08	2.6	456.	37.4	59.8	17.0	265.5	10.4	3.6	5.2	0.0	0.0	25.7	-139.5	40.7	-2.0	-180.3	-
2423.	14.0	29.99	16.0	397.	51.8	60.5	17.0	266.1	22.3	8.4	3.4	0.0	0.6	41.2	-137.4	39.0	-4.5	-171.4	22
2470.	14.0	30.57	21.0	494.	48.4	60.7	17.0	266.4	18.3	16.0	0.7	0.0	0.5	42.0	-141.8	34.5	-9.1	-171.4	22
2500.	14.0	30.94	21.1	503.	48.3	60.7	17.0	266.6	18.2	17.0	0.7	0.0	0.5	42.9	-142.9	33.5	-10.2	-176.4	-
2579.	21.0	31.92	3.0	551.	40.1	60.2	17.0	267.2	11.1	5.6	4.2	0.0	0.0	27.4	-140.3	40.6	-2.6	-175.9	2
2632.	21.0	32.57	2.0	531.	34.0	60.3	17.0	267.5	11.4	5.2	4.6	0.0	0.0	27.7	-146.9	33.9	-9.4	-175.9	2
2658.	15.0	32.89	14.0	405.	53.6	60.4	17.0	267.7	21.6	8.0	3.9	0.0	9.5	49.5	-146.2	31.0	-12.5	-172.2	22
2737.	15.0	33.87	13.0	400.	53.7	60.5	17.0	268.2	22.7	7.9	5.0	0.0	0.7	42.8	-139.8	37.3	-6.2	-172.2	22
2750.	15.0	34.03	12.9	399.	53.7	60.6	17.0	268.3	22.8	7.9	5.2	0.0	0.7	43.1	-140.1	37.0	-6.6	-177.1	-
2840.	16.0	35.14	14.0	440.	54.2	60.7	17.0	268.8	19.4	9.5	2.5	0.0	0.7	38.6	-136.1	41.7	-2.0	-172.9	22
2861.	16.0	35.41	13.0	423.	54.3	60.7	17.0	269.0	20.3	8.4	3.4	0.0	0.7	39.4	-136.9	41.0	-2.8	-172.9	22
2900.	16.0	35.89	15.2	478.	53.2	60.8	17.0	269.2	18.3	12.1	1.7	0.0	0.7	39.3	-138.0	39.8	-4.0	-177.8	-
2950.	16.0	36.51	15.6	496.	52.9	60.9	17.0	269.5	18.0	13.3	1.5	0.0	0.6	40.0	-139.3	38.6	-5.4	-177.8	-
3004.	16.0	37.17	16.0	515.	52.6	61.0	17.0	269.8	17.7	14.7	1.3	0.0	0.6	40.8	-140.6	37.2	-6.8	-172.9	22
3050.	16.0	37.75	10.6	405.	54.3	61.0	17.0	270.1	22.7	7.5	6.5	0.0	0.9	44.1	-142.4	35.4	-8.6	-177.8	-
3139.	17.0	38.85	12.0	453.	54.9	61.1	17.0	270.6	19.1	9.4	3.2	0.0	0.8	39.0	-137.6	40.9	-3.3	-173.6	22
3186.	17.0	39.43	13.0	485.	54.6	61.2	17.0	270.8	18.2	11.3	2.3	0.0	0.8	39.1	-138.3	40.2	-4.0	-173.6	22
3200.	17.0	39.60	13.1	490.	54.6	61.2	17.0	270.9	18.2	11.6	2.3	0.0	0.8	39.3	-138.6	39.9	-4.3	-178.5	-
3250.	17.0	40.22	13.3	506.	54.5	61.3	17.0	271.2	18.0	12.8	2.1	0.0	0.8	40.1	-139.6	38.9	-5.4	-178.5	-
3300.	17.0	40.84	13.5	521.	54.4	61.4	17.0	271.4	17.8	13.9	1.9	0.0	0.7	40.8	-140.6	37.9	-6.5	-178.5	-
3398.	17.0	42.06	14.0	552.	54.3	61.5	17.0	272.0	17.4	16.1	1.6	0.0	0.7	42.3	-142.6	35.9	-8.6	-173.6	22

FIGURE 10: Sample ALLMODES.DAT combined envelope table.

2.9) FOR034: Diagnostics

This file contains diagnostic and intermediate output, used to debug the program. It is not intended to be generally useful and is subject to change. Since the contents of fortran 34 are constantly changing no attempt is made here to document them fully. Suffice it to say that this large and generally useless file need not be generated; just don't use 'printout 3'. Now, with that said, there is a potentially useful table at the top of this file. It lists most of the values of the input parameters. If you have difficulty with a keyword, at least you may be able to determine whether it's getting in correctly. Unfortunately, not all input keywords and their values are reported. See the following figure 11 for a sample of the input echoed in unit 34.

```
SITELAT     =    51.44000       51.44000
SITELONG    =    79.16000       79.16000
AZIMUTH     =    275.0000      -1.000000
FREQ        =     5.00000       28.00000        1.000000
TXPOWER     =   0.2000000       53.01030
PULSEWIDTH  =    120.0000       120.0000              120
CIT         =    3.100000
XNOISE      =          -5
ANTTYPE     =          12             12
TIME        =    24.00000              0
YEAR        =        1991
MONTH       =           6
SUNSPOT     =    100.0000
FLUX        =    115.0030
KP          =   -1.700000
FOE         =    1.000000
FOF1        =    1.000000
FOF2        =    1.000000
FOES        =   0.7000000
BANDWIDTH   =    8333.333
WT          =    1.000000
KFAC        =    5.000000
LSCAN       =           0
FCLUT      =   9.9999998E-03
eclut      =   9.9999998E-03
TARSIZE     =    17.00000
SNR VS RANGE PLOTS
SLANT RANGE PLOTS
NORMAL SUMMARY PRINTOUT
+ INDIVIDUAL FREQUENCY PRINTOUT
+ DIAGNOSTIC PRINTOUT
                             o
                             o
                             o
                      < more cryptic data would follow >
```

FIGURE 11: Partial output from unit 34; echo of input values

PART III

FORTRAN implementation details

1.) Program description of RADARC

The purpose of part III is to walk the reader through the flow of RADARC, and to provide such program information as will facilitate the efforts of any user who wishes to understand the implementation details. A brief description of the function each routine performs accompanies the implementation information. These comments will be general enough to inform the reader who is unfamiliar with programming or specifically with the FORTRAN language. The reader should be forewarned that the structure is complicated and much care should be taken when changes to the code are considered.

Chart 1 is a diagram of RADARC showing the general flow of the program calls. There are four main subroutines that control the flow of RADARC. A short description of each of these "main" subroutines is presented here; descriptions of the rest of the subroutines follow. The major output is generated in subroutines AMPALL, SNRPLT, OPLOT, SETPLT and VPLOT.

IONGEN Retrieves the input data supplied by the user and developes the ionospheric parameters for the three layers (E, F1, and F2).

BAKSCT Backscatter control routine that calculates the vertical ionograms, reflectrix, oblique paths for all frequencies, and calculates and organizes some output.

RADAR Takes the oblique information from BAKSCT and evaluates the system parameters, losses, and calculates sporadic-E modes and losses.

SLANTY Gathers all information on modes, losses, and environmental noise and puts it in the form of the radar equation; it also gets the spread Doppler clutter by a call to ABILITY.

1.1) List of program routines with a short description

RADARC - Main program ···˙ ʰ controls all functions, sets named common, some data; gets date/time, and set ɪr function to avoid certain unwanted warnings during execution.

IONGEN - Called by main program RADARC to determine input and calculate ionospheric variables.

PRESET - Sets predefined program control variables; used in lieu of block data.

READIN - Reads the program control (input) variables from user input file on FOR011.

F1COF - Determines data base and calculates F1-layer parameters from monthly numerical coefficients

REDMAP - Reads the longterm ionospheric data file.

GEOM - Calculates geographic and geomagnetic parameters

CORDY - Calculates latitude and longitude of a point, given distance and azimuth from a known point.

MAGVAR - Calculates magnetic field and gyro-frequency.

MAGFIN - Cacluates the three magnetic field vectors.

MAP - Digitized map of the land boundries of the world

VERTIM - Calculates the time variation of ionospheric variables for sample areas.

ESIND - Calculates the sporadic-E MUF by a call to VERSY (see above). Data for the E_s-layer was calculated in REDMAP (see above).

TIMVAR - Calculates time dependence of the numerical maps of ionospheric variables.

EF1VAR -Calculates E and F1-layers ionospheric variables.

VERSY - Calculates geographic variation of the numerically mapped ionospheric variables.

YMAP - Calculates the F2-layer semi-thickness from numerical coefficients

F2VAR - Uses F2-layer numerical maps calculated by VERSY (see above)

POLARC - Determines the polar corrections for auroral oval and trough calculations when requested in the input file

CGMTIM - Determines corrected geomagnetic time by entry point to subroutine CLOCKS

JULIAN - Converts Gregorian date to Julian day; day set for 15th of month

GYRE - Computes solar ephemeris data of prediction time, in particular, right ascension, declination of sun and Greenwich SID time

GIMBAL - Updates the solar emphemeris data computed by GYRE to sidereal, corrected geomagnetic, and earth centered dipole magnetic time.

GEOMAG - Converts a point given in geographic coordinates to the corresponding corrected geomagnetic coordinates

DIPOLE - Converts from geographic coordinates to earth centered dipole system

COSD - Computes great circle distance between points on earth

BCKSCT - A call to INPUT obtains previously generated ionospheric parameters needed to calculate the electron density profile. INPUT calls INLEC, which reads electron density profiles or virtual heights (ionograms). This is a seldom used option.

ZERO - (Re)initializes data arrays.

LECDEN - Calculates the electron density profiles (parabolic layers) from the parameters read in by INPUT.

GENION - Integrates the true height electron density profiles to obtain a virtual height profile that will be used for all calculation from this point forward

ALOSFV - Calculates the deviative loss factors from the virtul height profile.

FOBBY - Generates the reflectrix and determines oblique frequencies.

CUSPFV - Computes values of the frequency/height parameters about the cusp and puts in reasonably smooth values that resemble those scaled from actual ionograms.

HEAD99 - Writes header information to FOR099.DAT for use on the combined rayset tables in FOR030 and ALLMODES.DAT.

AMPALL - Plot routine that sets up line printer character plots of signal-to- noise ratio for all frequencies and all modes of propagation.

SNRPRT - Routine that sets up variables and prints the tabular output

OPLOT - Plots the oblique ionograms for all frequencies and power levels.

READ99 - Generates and prints the combined rayset table in FOR030.

REA992 - Generates and prints the combined rayset table in ALLMODES.DAT.

RADAR - Backscatter control routine. Searches the oblique frequency tables for the reflectrix with constant frequency. If over the MUF these losses are calculated. Then the backscatter returns are computed.

ANTOO - Table look-up of gains for the selected antenna

TARGET - Computes the target size in dB above 1 meter^2.

SELION - Selects the closest control area to the ionospheric reflection. The ionospheric description at this control point is selected to represent the spherically symmetric model used over the that hop,which permits quick closed-form ray path calculations.

SELDST - Calculates all distances for iongoram generation

SETION - Determines the system losses. It calls SIGNT, a routine that permits a desired sea or land backscatter coefficient to be used. Adjustments have been made to this routine to deternimine losses over the MUF.

SIGNT - Sets backscatter coefficient of earth's surface

ESDIS - Calculates probability of sporadic-E modes and determine losses

GAUSS - Solves the probability function

SLANTY - Finds the raysets for the E, F1, and F2 layers. This routine gathers all results and puts them in the form of radar equation.

CGMCS - Calculates corrected geomagnetic coordinates

SYSSY - Determines auroral loss from tables

CHANY - Calculates man-made and galactic noise level at receiver

NOISY - Computes atmospheric noise levels from numerical maps

GENFAM - Determines frequency dependence of atmospheric noise

ABILITY_V3 - Calcultes spread Doppler clutter by Elkins method

GLOSS - Calculates the reflection loss per hop for multi-hop paths

CUSPIN - Calculates angles for the modified cusp values of E-F1 and f!-F2 layers

ESSNR - Determines raysets and all variables used in RADAR equation associated with sporadic-E modes.

BRING - Calculates bearing from one point on the globe to another, given the geographic coordinates of the points.

DTOG - Computes complex function of three variables

FPOK - Determines probability of spread Doppler

PEIR- Computes the value of E-layer clutter probability (F-layer clutter with entry point PFIR)

MERFI - Inverse error function

PINCLY - Determines overall magnetic field by summation

SOLR - Updates orbital elements of of epoch

FKEP - Calculates true anomaly for Julian day

XFR3 - Computes rotation matrix element

SETPLT - Plot control routine that sets up variables to be plotted

ALLFREQ - Plots range vs amplitude showing which frequency was best at each range interval

AMPLOT - Same as allfreq, but shows best mode at each range interval

ESTERP - Sets indicies for sporadic E-layer printer plots

INTERP - Sets indicies for regular layer printer plots (E,F1, and F2)

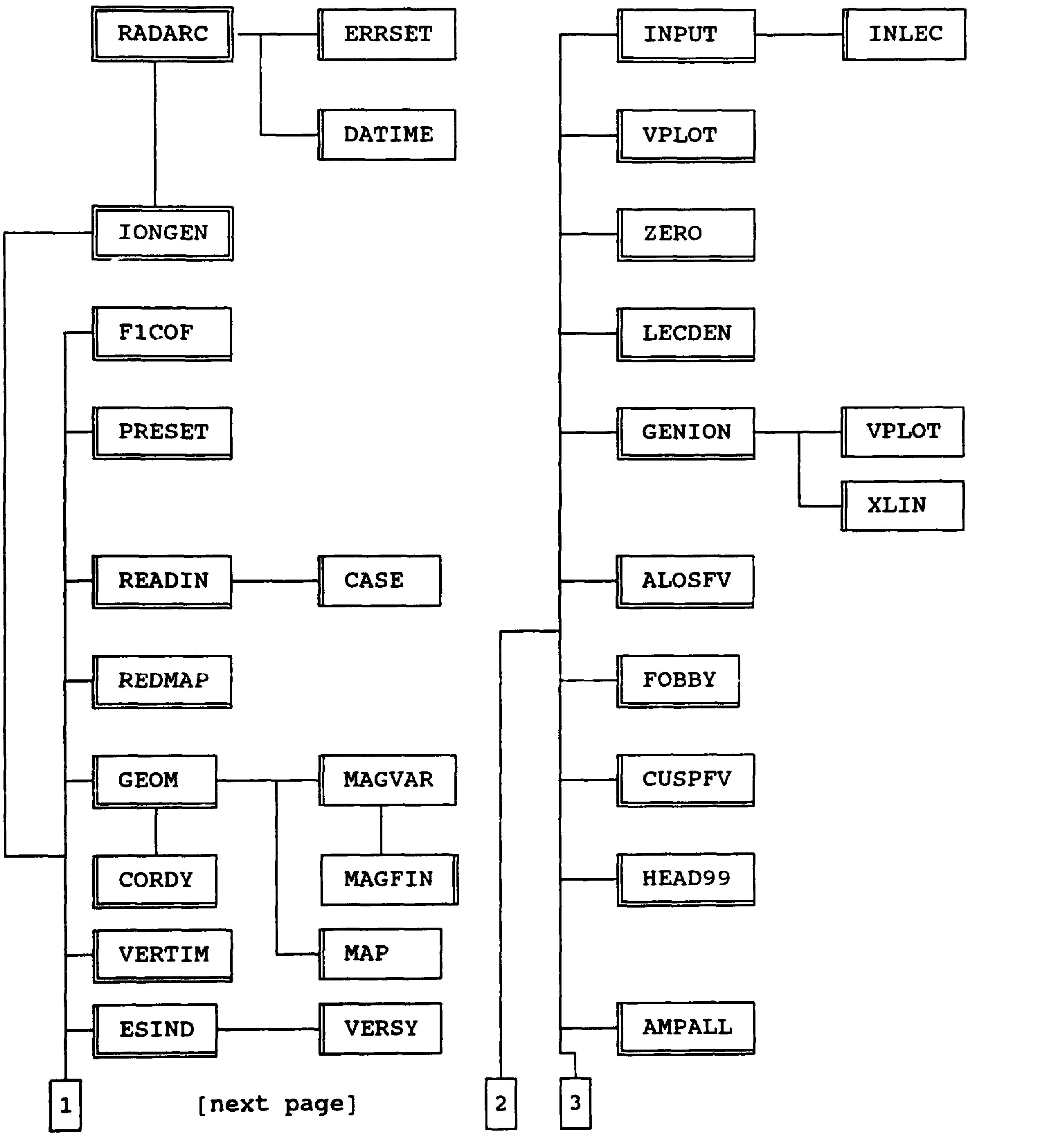
CPTERP - Sets indicies for plot cusp inserts

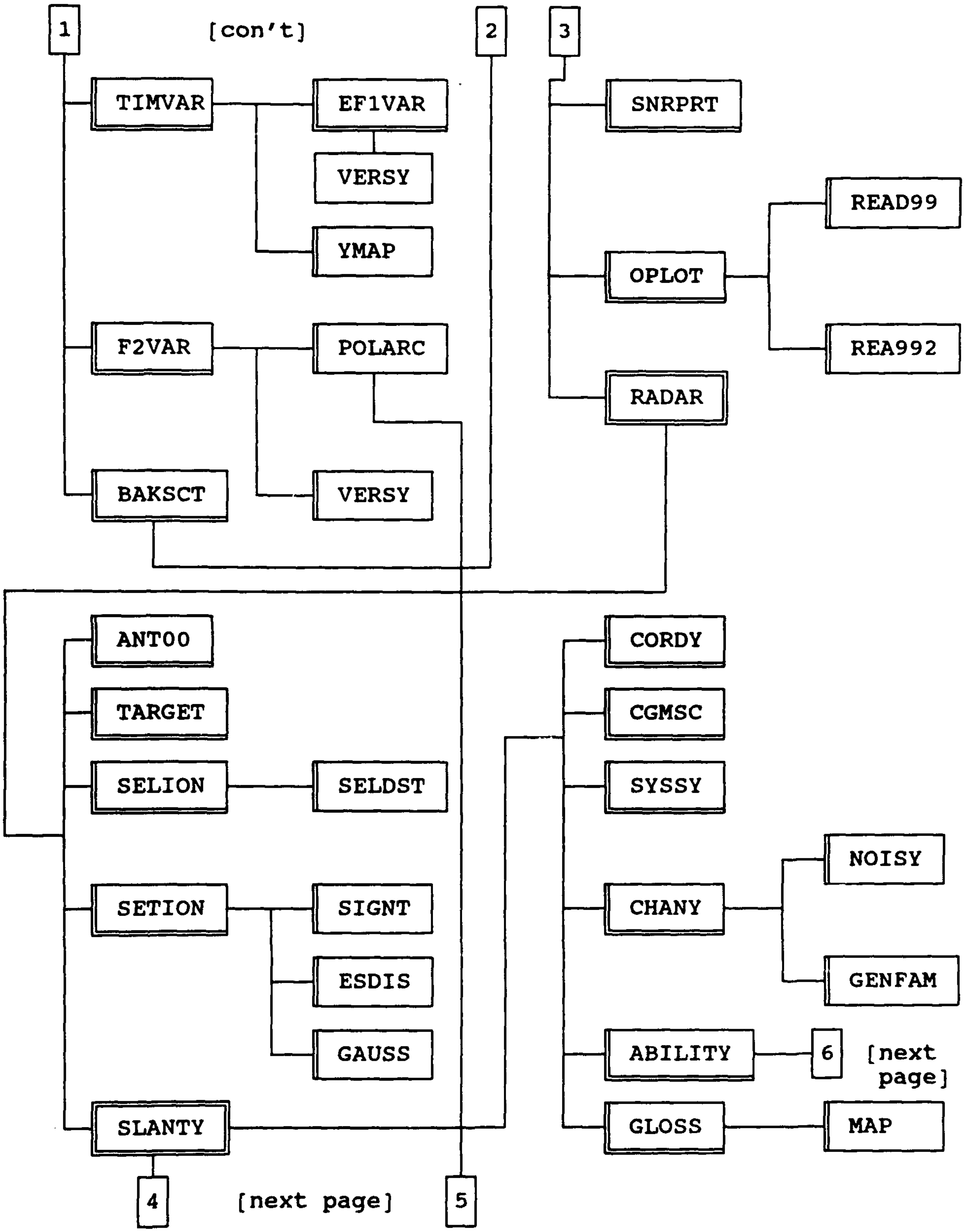
CUSPSG - Calculates ray sets in the cusp region between regular layers

SETCP - Finds signal-to-noise values for cusp region

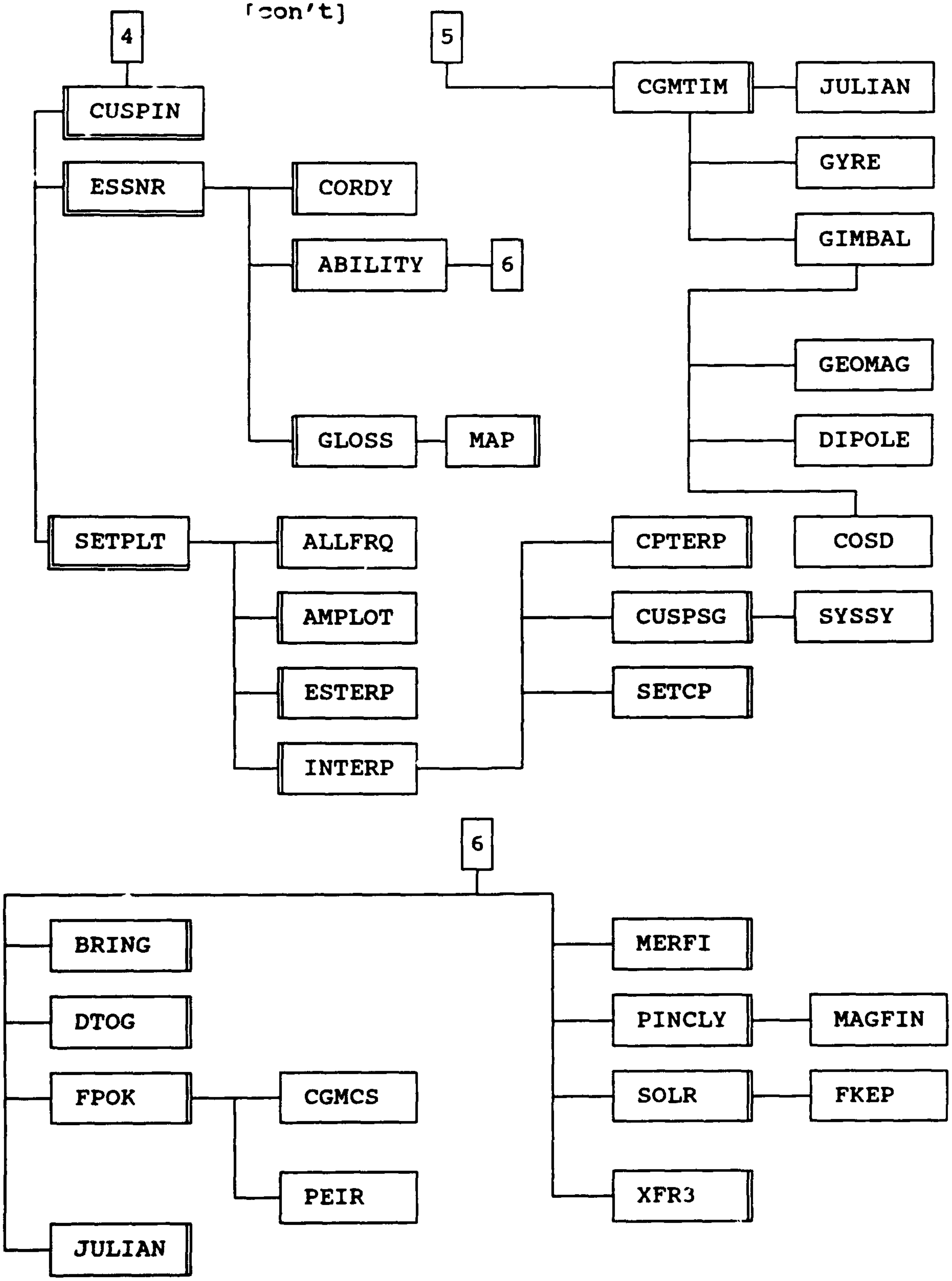
1.2) Chart of RADARC calling structure

RADARC DIAGRAM




1
[con't]
2
3
TIMVAR
EF1VAR
VERSY
YMAP
F2VAR
POLARC
BAKSCT
VERSY
SNRPRT
OPLOT
READ99
REA992
RADAR
ANT00
TARGET
SELION
SELDST
SETION
SIGNT
ESDIS
GAUSS
SLANTY
CORDY
CGMSC
SYSSY
CHANY
NOISY
GENFAM
ABILITY
6
[next page]
GLOSS
MAP
4
[next page]
5

[con't]


4
CUSPIN
ESSNR
CORDY
ABILITY
6
GLOSS
MAP
SETPLT
ALLFRQ
AMPLOT
ESTERP
INTERP
5
CGMTIM
JULIAN
GYRE
GIMBAL
GEOMAG
DIPOLE
COSD
CPTERP
CUSPSG
SYSSY
SETCP
6
BRING
DTOG
FPOK
CGMCS
PEIR
JULIAN
MERFI
PINCLY
MAGFIN
SOLR
FKEP
XFR3

1.3) Individual module implementation information

This section section lists the routines in alphabetical order and provides some information about the arguments in the calls (if any), the purpose of the routines, which common data areas are accessed (if any), what variables and arrays are defined, and what functions and subroutines each routine in turn references.

Module: ABILITY_V3

```
CALL:  SUBROUTINE ABILITY_V3 (FREQ,DELAY,TOA,ABPS1,VHIGH,
     1                        ATMON, GMT,MON,RANGE,AZIM,NHOPS,
     2                        CPDB)
```

Call arguments:

FREQ	Current operating frequency, MHz.
DELAY	Total slant time delay, ms.
TOA	Take-off angle, degrees.
ABPS1	one-way deviative, non-deviative, and obscuration losses, db.
VHIGH	virtual height, km.
ATMON	atmospheric noise, dBkTb.
GMT	Greenwhich Mean Time.
MON	Month
RANGE	ground range to target, kilometers
AZIM	Azimuth to target, degrees
NHOPS	Number of ionospheric hops
** CPDB	Clutter power in dB

** returned value

Purpose: Calculates spread Doppler clutter by Elkins method

Included Commons:	Size (4 byte words)
POK	(84)
CC	(16)
PIR	(28)
AVAIL_INP	(120)
ANT	(368)
TRACE	(4)

Entry points: ABILITY_V3

Variables:

R*4	ABPS1	R*4	ABPS2	R*4	ABSA1	R*4	ABSA2
R*4	ANTGAIN	R*4	ATMON	CHAR	AT_CHAR	R*4	AZ2
R*4	AZIM	R*4	BANDW	R*4	BEAMW	R*4	BRT
R*4	BUGS	R*4	BWIDTH	R*4	C	R*4	CO
R*4	CCLT	R*4	CIT	R*4	CITDB	R*4	CLAT
R*4	CLG	R*4	CLON	R*4	CLT	R*4	CPDB
CHAR	CP_CHAR	R*4	CSDC	R*4	CSDY2	R*4	CSLO
R*4	CZ	R*4	CZ1	R*4	CZ2	R*4	CZT
R*4	D2R	R*4	DB	R*4	DEL	R*4	DELAY
R*4	DELR	R*4	DENOM	R*4	ECLUT	R*16	ERF1
R*4	ERFN	R*4	ETA	R*4	ETABAR	R*4	FCLUT
R*4	FDNFG	R*4	FOCUSDB	R*4	FPI3DB	R*4	FPOX
R*4	FREQ	R*4	GDEC	R*4	GHRMT	R*4	GLAT
R*4	GLN	R*4	GLON	R*4	GLT	R*4	GMT
R*4	GRT	C*8	GTOD	R*4	HIGH	R*4	HOP_RNGE
I*4	IER	I*4	ITRC	I*4	IYEAR	I*4	JDAY
R*4	KFAC	R*4	KFACT	R*4	LAT2	R*4	LAT2D
R*4	LINTRP	R*4	LN10	R*4	LSCAN	I*4	MON
I*4	ND	R*4	NFAC	R*4	NFG	I*4	NHOP
I*4	NHOPS	R*4	NS	I*4	NSC	R*4	NSEDB
I*4	NY	R*4	ORTANG	R*4	ORTAP	R*4	ORTMAG
R*4	PO	R*4	PCBAR	R*4	PD	R*4	PG

Arrays:

R*4	AGAIN	(45)
R*4	ARG	(3)

ABILITY_V3 (cont.)

```
  R*4   GRLOS              (45)
  R*4   ROT                (3, 3)

 Subroutines and Functions Referenced:
  R*4   BRING              C*8  DTOG                 FPOK              I*4  JULIAN
  R*4   MTH$ASIN           R*4  MATH$ATAN       R*4  MTH$COS           R*4  MTH$SI
  R*4   SOLR                     XFR3
```

Module: ABSAUR

CALL: SUBROUTINE ABSAUR(PHI,T,PHD,FREQ,ABSA)

Call Arguments:
PHI Corrected geomagnetic latitude at D-layer penetration, degrees.
T Corrected geomagnetic time at d-region penetration.
PHD Incident angle of ray at D-layer height, radians
FREQ Current operating frequency, MHz
** ABSA Auroral absorption loss, dB

** returned value

Purpose: calculate auroral absorption for availability calculations only

Included Commons:
no user defined commons

Entry points: ABSAUR

Variables:

R*4	ABSA	R*4	AT	R*4	ATT	R*4	DIF
R*4	FREQ	I*4	I	I*4	J	R*4	PHD
R*4	PHI	R*4	T				

Arrays:
R*4 AB (13)

Subroutines and Functions Referenced:
R*4 MTH$COS R*4 MTH$EXP

Module: ALLFRQ

CALL: SUBROUTINE ALLFRQ

Purpose: Plots range vs amplitude showing what frequency was best at each range interval

Included Commons:	Size (4 byte words)
ALLAMP	(10656)
APLT	(56)
FOLO	(9360)
ESTAB	(1332)
FRQCHK	(8)
PLTAB	(9328)
XXXX	(46900)

Entry points: ALLFRQ

Variables:

R*4	BMONS	R*4	FNOISE	R*4	FREQ	I*4	I
I*4	IANT	I*4	IAZMTH	I*4	IFIRST	I*4	IFR
I*4	IFREQ	I*4	IPWUS	I*4	IREFF	I*4	ISSN
I*4	IT	I*4	J	I*4	JFREQ	I*4	JJ
I*4	KMAX	I*4	MAXFRQ	R*4	PREFRQ	R*4	PWR
R*4	SNOISE	R*4	X1	R*4	Y1		

Arrays:

R*4	AFREQ	(35)
R*4	AMP	(8, 45)
R*4	ANOISE	(35)
R*4	CNR	(8, 45)
R*4	CPDB	(8, 45)
R*4	DELH	(10, 45)
R*4	DELI	(10, 45)
I*4	IOSNR	(333, 35)
I*4	ISMB	(1332)
I*4	ISNR	(1332)
I*4	LAYSMB	(333, 4)
I*4	LAYSNR	(333, 4)
I*4	LESNR	(333)
I*4	LLAYER	(333, 3)
I*4	LSLAY	(333)
I*4	LSMB	(36)
I*4	LSNR	(333, 3)

Module: ALOSFV

CALL: SUBROUTINE ALOSFV

Purpose: Calculates the deviative loss factors from the virtual height profile.

Included Commons: Size (4 byte words)

HGH	(28800)
INP	(68)
ION	(368)
RADR	(24)

Entry points: ALOSFV

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	CF	R*4	DELINC
R*4	DLH	R*4	FAC	R*4	FFAC	R*4	FV
R*4	GMT	R*4	HZ	I*4	I	I*4	ICCP
I*4	IE	I*4	IEXD	I*4	IFF	I*4	IND
I*4	IST	I*4	JDIN	I*4	K	I*4	K3
I*4	KND	I*4	L	I*4	MAN	I*4	METH
I*4	METHOD	I*4	MONS	R*4	PWID	R*4	PWP
R*4	SSN	R*4	X1	R*4	Y1		

Arrays:

R*4	A	(3)
R*4	AFAC	(240, 10)
R*4	ALOOK	(6)
R*4	FFAK	(2)
R*4	FI	(10, 3)
R*4	HI	(10, 3)
R*4	HM	(2)
R*4	HPRIM	(240, 10)
R*4	HTRUE	(240, 10)
R*4	YI	(10, 3)

Subroutines and Functions Referenced:

R*4	MTH$ALOG	R*4	MTH$EXP

Module: AMPALL

CALL: SUBROUTINE AMPALL (FOBMAX,IRAN)

Call Arguments:

FOBMAX	Maximum frequency to examine, MHz
IRAN	Which page of this figure is current

** returned value

Purpose: Plot routine that sets up line printer character plots of signal-to-noise ratio for all frequencies and all modes of propagation.

Included Commons:	Size (4 byte words)
ALLAMP	(10656)
APLT	(36)
INP	(72)
LUNITS	(48)
RADR	(12)
RAD2AVA	(40)

Entry points: AMPALL

Variables:

R*4	AZMTH	R*4	BANDW	R*4	BMONS	R*4	BWIDTH
R*4	ECLUT	R*4	FCLUT	R*4	FOBMAX	R*4	FREQ
R*4	GMT	I*4	I	I*4	IAZMTH	I*4	IBCL

Arrays:

R*4	ALOOK	(6)
I*4	ILAB	(2)
I*4	IPRNT	(111)
I*4	IRANGE	(12)
I*4	ITIME	(29)
I*4	J1	(3)
I*4	J2	(3)
I*4	J3	(3)
I*4	LAYSMB	(333, 4)
I*4	LAYSNR	(333, 4)
I*4	LSMB	(36)
I*4	MARGS	(45)
I*4	NL	(45)
I*4	NNLAT	(2)
I*4	NNLON	(2)

Module: AMPLOT

CALL: SUBROUTINE AMPLOT (INT,IRAN)

Call Arguments:

INT	Vestigial, no longer used.
IRAN	Which page of this figure is current

** returned value

Purpose: Same as allfreq, but shows best mode at each range interval

Included Commons:	Size (4 byte words)
APLT	(56)
DAT	(192)
ESTAB	(3996)
INP	(72)
LUNITS	(48)
PLT	(3640)
PLTAB	(11992)
RADR	(16)
RAD2AVA	(40)
TIME	(23)

Entry points: AMPLOT

Variables:

R*4	AK	R*4	ANOISE	R*4	AZMTH	R*4	BANDW
R*4	BK	R*4	BMONS	R*4	BWIDTH	R*4	C180
R*4	C360	R*4	CK	CHAR	DATETIME	R*4	DELINC
R*4	DK	R*4	ECLUT	R*4	EEK	R*4	EK
R*4	FCLUT	R*4	FNOISE	R*4	FREQ	R*4	GLG
R*4	GLT	R*4	GMT	I*4	I	I*4	IANT
I*4	IAZMTH	I*4	IBCL	I*4	IC	I*4	ICC
I*4	IDBW	I*4	IDN	I*4	IDUMM	I*4	IDX
I*4	IDY	I*4	IES	I*4	IEXD	I*4	IFR
I*4	IGND	I*4	II	I*4	IK	I*4	INOW
I*4	INT	I*4	IPHASE	I*4	IPWUS	I*4	IRAN
I*4	IRAT	I*4	IREFF	I*4	ISCALE	I*4	ISNR
I*4	ISSN	I*4	IT	I*4	ITOP	I*4	IUP
I*4	J	I*4	KFAC	I*4	KMAX	I*4	L
I*4	LANT	I*4	LAYMAX	I*4	LCON	I*4	LGEO
I*4	LIONO	I*4	LMAP	I*4	LNOISE	I*4	LOUT1
I*4	LOUT2	I*4	LOUT3	I*4	LSCAN	I*4	LSCRT
I*4	LSEMI	I*4	LTAR	I*4	LX	I*4	M
I*4	MAN	I*4	METH	I*4	METHOD	I*4	MONS
I*4	NBLANK	I*4	NC	I*4	NLAT	I*4	NLON
I*4	NRSCANS	I*4	NS	R*4	PI2	R*4	PWID
R*4	PWP	R*4	PWR	R*4	REFF	R*4	RXNF
R*4	RZ	R*4	SCVLM	R*4	SNOISE	R*4	SSN
R*4	TXLAT	R*4	TXLON	R*4	WT	R*4	X1
R*4	X2	R*4	Y1	R*4	Y2		

Arrays:

R*4	ALOOK	(6)
R*4	AMON	(12)
I*4	IDIST	(8, 45)
I*4	IDLAY	(8, 45)
I*4	ILAB	(2)
I*4	ILAYER	(45, 4)
I*4	IPRNT	(111)

AMPLOT (cont.)

```
  I*4   IRANGE          (12)
  I*4   ITIME           (29)
  I*4   J1              (3)
  I*4   J2              (3)
  I*4   J3              (3)
  I*4   JNUM            (10)
  I*4   LANG            (333, 3)
  I*4   LESANG          (333)
  I*4   LESNR           (333)
  I*4   LLAYER          (333, 3)
  I*4   LSLAY           (333)
  I*4   LSNR            (333, 3)
  I*4   MARGS           (45)
  I*4   NL              (45)
  I*4   NNLAT           (2)
  I*4   NNLON           (2)
  I*4   NT              (45)
  R*4   SUN             (2, 12)
```

Module: ANT00

CALL: SUBROUTINE ANTOO (IGAIN)

Call Arguments:
** IGAIN 2-way antenna gain, dB

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANTOO

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	GAIN
R*4	GAZM	I*4	I	I*4	IGAIN	R*4	R2D
R*4	SIGBAK						

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)

Module: ANT01

CALL: SUBROUTINE ANT01 (F,IFR)

Call Arguments:
F current operating frequency, MHz
IFR antenna type (ANTTYP on input)
** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
INP	(68)
RADR	(24)

Entry points: ANT01

Variables:

R*4	AMPL	R*4	ANGLE	R*4	AZMTH	R*4	BWIDTH
C*8	CPART	R*4	DED	R*4	DELINC	C*8	EC
R*4	EI	R*4	EPS	R*4	F	R*4	FREQ
R*4	GAIN	R*4	GAZM	R*4	GFIX	R*4	GMT
R*4	HWIDTH	I*4	I	I*4	ICCP	I*4	IEXD

Arrays:

R*4	A	(4)
R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	BEMWD	(30)
R*4	D	(4)
R*4	FFAK	(2)
R*4	GRLOS	(45)
R*4	PHI	(4)

Subroutines and Functions Referenced:

R*4	MTH$ALOG	R*4	MTH$ATAN2	R*4	MTH$CABS	R*4	MTH$CO

Module: ANT02

CALL: SUBROUTINE ANT02 (FREQ,IPHASE)

Call Arguments:
  FREQ   current operating frequency, MHz
  IPHASE   antenna type (ANTTYP on input)
 ** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT02

Variables:

R*4	AZI	R*4	AZMTH	R*4	BORE	R*4	BWIDTH
R*4	D2R	R*4	FLAM	R*4	FREQ	R*4	GAZM
R*4	GTGR	I*4	I	I*4	IPHASE	R*4	R2D
R*4	SIGBAK	R*4	SLEW	R*4	SLEWDB		

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GAIN	(45)
R*4	GRLOS	(45)

Subroutines and Functions Referenced:
 R*4 MTH$ALOG

Module: ANT03

CALL: SUBROUTINE ANT03 (FREQ,IPHASE)

Call Arguments:
FREQ current operating frequency, MHz
IPHASE antenna type (ANTTYP on input)
** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT03

Variables:

R*4	ADJDB	R*4	AZI	R*4	AZMTH	R*4	BORE
R*4	BWIDTH	R*4	D2R	R*4	FREQ	R*4	FREQQ
R*4	GAZM	I*4	I	I*4	IFREQ	I*4	IP1
I*4	IPHASE	I*4	IREAD	I*4	J	I*4	JIN
R*4	R2D	R*4	SIGBAK	R*4	SLEW	R*4	SLEWDB
R*4	XFREQ						

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(16, 45)
R*4	TXDATA	(16, 45)

Subroutines and Functions Referenced:
FOR$CLOSE FOR$EXIT FOR$OPEN R*4 MTH$AL

Module: ANT04

CALL: SUBROUTINE ANT04 (FREQ)

Call Arguments:
FREQ current operating frequency, MHz

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT04

Variables:

R*4	ADJDB	R*4	AZI	R*4	AZMTH	R*4	BORE
R*4	BWIDTH	R*4	D2R	R*4	FREQ	R*4	FREQQ
R*4	GAZM	I*4	I	I*4	IFREQ	I*4	IP1
I*4	IREAD	I*4	J	I*4	JIN	R*4	R2D
R*4	RXBW	R*4	RXGAIN	R*4	SIGBAK	R*4	SLEW
R*4	SLEWDB	R*4	TXBW	R*4	TXGAIN	R*4	XFREQ

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GFLOS	(45)
R*4	RXDATA	(45, 22)
R*4	TXDATA	(22, 45)

Subroutines and Functions Referenced:

FOR$CLOSE	FOR$EXIT	FOR$OPEN	R*4 MTH$AL

Module: ANT05

CALL: SUBROUTINE ANT05 (F)

Call Arguments:
F current operating frequency, MHz

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
RADR	(24)

Entry points: ANT05

Variables:

R*4	AMP	R*4	AMPDB	R*4	BWIDTH	C*8	CPART
R*4	D2R	R*4	DED	R*4	DELINC	C*8	EC
R*4	EI	R*4	EPS	R*4	F	R*4	FREQ
R*4	GAZM	R*4	GROT	R*4	HWIDTH	I*4	I
I*4	IFREQ	R*4	K	I*4	L	R*4	PWID
R*4	PWP	C*8	R	R*4	R2D	R*4	RAMPL
R*4	RANGLE	R*4	RPART	R*4	RX	R*4	RY
R*4	SIGBAK	R*4	SIGMA	C*8	SUM	R*4	X
C*8	Y						

Arrays:

R*4	A	(2)
R*4	AGAIN	(45)
R*4	BEMWD	(30)
R*4	D	(2)
R*4	FFAF	(2)
R*4	GRLOSS	(45)
R*4	PHI	(2)

Subroutines and Functions Referenced:

R*4	MTH$ALOG	R*4	MTH$ATAN2	R*4	MTH$CABS	R*4	MTH$CO

Module: ANT06

CALL: SUBROUTINE ANT06 (FREQ)

Call Arguments:
  FREQ   current operating frequency, MHz

 ** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT06

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FDEL
R*4	FREQ	R*4	FTEST	R*4	GAZM	I*4	I
I*4	IDX	I*4	IDX1	I*4	IFREQ	I*4	IP1
I*4	IREAD	I*4	J	I*4	JIN	R*4	R2D
R*4	SIGBAK	R*4	XFREQ				

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(45, 30)
R*4	TXDATA	(45, 30)
R*4	WIDTH	(14)

Subroutines and Functions Referenced:
      FOR$CLOSE   FOR$EXIT   FOR$OPEN

Module: ANT07

CALL: SUBROUTINE ANT07 (FREQ)

Call Arguments:
  FREQ   current operating frequency, MHz

 ** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT07

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FDEL
R*4	FREQ	R*4	FTEST	R*4	GAZM	I*4	I
I*4	IDX	I*4	IDX1	I*4	IFREQ	I*4	IP1
I*4	IREAD	I*4	J	I*4	JIN	R*4	R2D
R*4	SIGBAK	R*4	XFREQ				

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(45, 30)
R*4	TXDATA	(45, 30)
R*4	WIDTH	(13)

Subroutines and Functions Referenced:
  FOR$CLOSE   FOR$EXIT   FOR$OPEN

Module: ANT08

CALL: SUBROUTINE ANT08 (FREQ)

Call Arguments:
FREQ current operating frequency, MHz

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT08

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FREQ
R*4	FREQQ	R*4	GAZM	I*4	I	I*4	IFREQ
I*4	IP1	I*4	IREAD	I*4	J	I*4	JIN
R*4	R2D	R*4	SIGBAK	R*4	XFREQ		

Arrays:

R*4	AGAIN	(45)
R*4	ANTDAT	(2570)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(16, 45)
R*4	TX1DAT	(25, 45)
R*4	TX2DAT	(25, 45)

Subroutines and Functions Referenced:

FOR$CLOSE	FOR$EXIT	FOR$OPEN	R*4 MTH$EX

Module: ANT09

CALL: SUBROUTINE ANT09 (FMHZ,VSTEER)

Call Arguments:

FMHZ	current operating frequency, MHz
VSTEER	vertical steer angle of the array, degrees

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT09

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	ELDEG
R*4	ELINC	R*4	ELSTEP	R*4	FMHZ	R*4	FREQ
R*4	FREQQ	R*4	GAZM	I*4	I	I*4	IFREQ
I*4	IFST	I*4	IP1	I*4	IREAD	I*4	J
I*4	J1	I*4	J2	I*4	J3	I*4	J4
I*4	J5	I*4	JIN	I*4	NUM	R*4	PI
R*4	PSI	R*4	R2D	R*4	SIGBAK	R*4	SINPSI
R*4	SPACE	R*4	VSTEER	R*4	XFREQ		

Arrays:

R*4	AGAIN	(45)
R*4	C	(15)
R*4	CM	(15)
R*4	DUM	(15)
R*4	DUMMY	(6)
R*4	FDB	(45)
R*4	FE	(15)
R*4	FS	(45)
R*4	FT	(45)
R*4	GRLOS	(45)
R*4	H	(15)
R*4	RXDATA	(16, 45)
R*4	W	(15)

Subroutines and Functions Referenced:

FOR$CLOSE	FOR$EXIT	FOR$OPEN	R*4 MTH$AL
TAYLOR			

Module: ANT10

CALL: SUBROUTINE ANT10 (FREQ)

Call Arguments:
  FREQ   current operating frequency, MHz

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT10

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FDEL
R*4	FREQ	R*4	FTEST	R*4	GAZM	I*4	I
I*4	IDX	I*4	IDX1	I*4	IFREQ	I*4	IP1
I*4	IREAD	I*4	J	I*4	JIN	R*4	R2D
R*4	SIGBAK	R*4	XFREQ				

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(30, 45)
R*4	TXDATA	(30, 45)
R*4	WIDTH	(15)

Subroutines and Functions Referenced:
FOR$CLOSE   FOR$EXIT   FOR$OPEN

Module: ANT11

CALL: SUBROUTINE ANT11 (FREQ)

Call Arguments:
FREQ   current operating frequency, MHz

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT11

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FDEL
R*4	FREQ	R*4	GAZM	I*4	IFREQ	I*4	IHI
I*4	ILO	I*4	IREAD	I*4	J	I*4	JIN
R*4	R2D	R*4	SIGBAK				

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(45, 30)
R*4	TXDATA	(45, 30)
R*4	WIDTH	(30)

Subroutines and Functions Referenced:
FOR$CLOSE   FOR$EXIT   FOR$OPEN

Module: ANT12

CALL: SUBROUTINE ANT12 (FREQ)

Call Arguments:
FREQ current operating frequency, MHz

** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT12

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FDEL
R*4	FREQ	R*4	GAZM	I*4	IFREQ	I*4	IHI
I*4	ILO	I*4	IREAD	I*4	J	I*4	JIN
R*4	R2D	R*4	SIGBAK				

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(45, 30)
R*4	TXDATA	(45, 30)
R*4	WIDTH	(30)

Subroutines and Functions Referenced:
FOR$CLOSE FOR$EXIT FOR$OPEN

Module: ANT13

CALL: SUBROUTINE ANT13 (FREQ)

Call Arguments:
  FREQ   current operating frequency, MHz

 ** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT13

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FDEL
R*4	FREQ	R*4	GAZM	I*4	IFREQ	I*4	IHI
I*4	ILO	I*4	IREAD	I*4	J	I*4	JIN
R*4	R2D	R*4	SIGBAK	R*4	WIDTH		

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXDATA	(45, 30)
R*4	TXDATA	(45, 30)

Subroutines and Functions Referenced:

FOR$CLOSE	FOR$EXIT	FOR$OPEN

Module: ANT14

CALL: SUBROUTINE ANT14 (FREQ)

Call Arguments:
  FREQ   *current operating frequency, MHz*

 ** returned value

Purpose: Table look-up of gains for the selected antenna

Included Commons:	Size (4 byte words)
ANT	(372)
DAT	(8)
INP	(28)

Entry points: ANT14

Variables:

R*4	AZMTH	R*4	BWIDTH	R*4	D2R	R*4	FDEL
R*4	FREQ	R*4	GAZM	I*4	IFREQ	I*4	IHI
I*4	ILO	I*4	IREAD	I*4	J	I*4	JIN
R*4	R2D	R*4	SIGBAK				

Arrays:

R*4	AGAIN	(45)
R*4	DUMMY	(6)
R*4	GRLOS	(45)
R*4	RXBW	(35)
R*4	RXDATA	(45, 35)
R*4	TXBW	(35)
R*4	TXDATA	(45, 35)

Subroutines and Functions Referenced:
      FOR$CLOSE   FOR$EXIT   FOR$OPEN

Module: ANTGAIN

```
CALL: REAL FUNCTION ANTGAIN(toa,freq,MATRIX)

 Call Arguments:
   TOA       Take-off angle, degrees
   FREQ      current operating frequency, MHz
   MATRIX    target cross section, dB

  ** returned value

 Purpose:    performs a two-dimensional interpolation for antenna gain and target
             cross section matrices.


 Included Commons:
  no user defined commons

 Entry points: ANTGAIN

 Variables:
  R*4    DELTAE        R*4    DELTAF        R*4    ELEVO         R*4    ELEV1
  R*4    ELEVHI        R*4    ELEVINC       R*4    FREQ          R*4    FREQO
  R*4    FREQ1         R*4    FREQHI        R*4    FREQINC       R*4    G1
  R*4    G2            R*4    G3            R*4    G4            R*4    GAINE1
  R*4    GAINE2        I*4    INDXE         I*4    INDXF         I*4    NELEV
  I*4    NFREQ         R*4    TOA

 Arrays:
@ R*4   MATRIX          (20, 20)
```

Module: AURAB

CALL: REAL FUNCTION AURAB(FREQ,RANG,AZ,VH,UT,RLAT,RLONG,CSLO)

Call Arguments:

FREQ	Current operating frequency, MHz
RANG	range to target in km
AZ	azimuth to target, degrees
VH	virtual height of path, Km
UT	Universal time
RLAT	lat coordinate of radar, degrees.
RLONG	longitude coordinate of radar, degrees.
CSLO	geomagnetic longitude (correction to geomagnetic time), degrees.

** returned value

Purpose: gets parameters for auroral absorption calculation, then calls absaur for loss (for availability only).

Included Commons:
no user defined commons

Entry points: AURAB

Variables:

R*4	ABSA1	R*4	ABSA2	R*4	ARGUMENT	R*4	AZ
R*4	AZLIM	R*4	BETA	R*4	CB	R*4	CLON1
R*4	CLON2	R*4	COLAT	R*4	CSLO	R*4	D2R
R*4	DLAT	R*4	DPHI	R*4	FREQ	R*4	GAM
R*4	HD	R*4	PHD	R*4	PHF	R*4	PHI
R*4	PHI1	R*4	PHI2	R*4	PI	R*4	RANG
R*4	RATD	R*4	RATF	R*4	RD1	R*4	RD2
R*4	RE	R*4	RFAC1	R*4	RFAC2	R*4	RLAT
R*4	RLONG	R*4	SB	R*4	T1	R*4	T2
R*4	TEMP1	R*4	TEMP2	R*4	UT	R*4	VH

Subroutines and Functions Referenced:

	ABSAUR		CGMCS	R*4	MTH$ACOS	R*4	MTH$AS
R*4	MTH$SIN	R*4	MTH$TAN				

Module: BAKSCT

CALL: SUBROUTINE BAKSCT

Purpose: Backscatter control routine that calculates the vertical ionograms, reflectrix, oblique paths for all frequencies; calculates and organizes some output. A call to INPUT obtains previously generated ionospheric parameters needed to calculate the electron density profile. INPUT calls INLEC, which reads electron density profiles or virtual heights (ionograms). This is a seldom used option.

Included Commons:	Size (4 byte words)
APLT	(60)
DAT	(192)
FRQCHK	(8)
INP	(68)
ION	(436)

Entry points: BAKSCT

Variables:

R*4	AK	R*4	AZMTH	R*4	BK	R*4	C180
R*4	C360	R*4	CK	R*4	DK	R*4	EEK
R*4	EK	R*4	FBEG	R*4	FEND	R*4	FNOISE

Arrays:

R*4	ALOOK	(6)
I*4	AMON	(12)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)
R*4	FREL	(15)
R*4	HE	(10)
R*4	HF1	(10)
R*4	HF2	(10)
R*4	SUN	(2, 12)
R*4	YME	(10)
R*4	YMF1	(10)
R*4	YMF2	(10)

Subroutines and Functions Referenced:

ALOSFV	AMPALL	CUSPFV	FOBBY
INPUT	LECDEN	OPLOT	RADAR

Module: bring

CALL: real function bring(cclat,cclon,sslat,sslon)

Call Arguments:

cclat	latitude coordinate of first point, radians.
cclon	longitude coordinate of first point, radians.
sslat	latitude coordinate of second point, radians.
sslon	longitude coordinate of second point, radians.

** returned value

Purpose: Calculates bearing from first point to second point. Used for transmitter to spread Doppler clutter region

Included Commons:
no user defined commons

Entry points: BRING

Variables:

R*4	BRT	R*4	CCLAT	R*4	CCLON	R*4	DLONG
R*4	EPSLON	R*4	GCD	R*4	PI	R*4	PI2
R*4	QCOS	R*4	SSLAT	R*4	SSLON		

Subroutines and Functions Referenced:

R*4	MTH$ACOS	R*4	MTH$COS	R*4	MTH$SIGN	R*4	MTH$SI

Module: CASE

CALL: SUBROUTINE CASE (C,ISW)

Call Arguments:
C   character string to convert
ISW   integer flag to set upper(+)/lower(-) case.

** returned value

Purpose: converts a character string to upper/lower case

Included Commons:
no user defined commons

Entry points: CASE

Variables:

CHAR	C	I*4	I	I*4	ICVALUE	I*4	ISW
I*4	NHI1	I*4	NHI2	I*4	NLO1	I*4	NLO2

Module: CGMCS

CALL: SUBROUTINE CGMCS(XG,YG,FO,GO)

Call Arguments:

XG	geographic latitude coordinate of point, degrees.
YG	geographic longitude coordinate of point, degrees.
FO	corrected geomagnetc latitude coordinate of point, degrees.
GO	correceted geomagnetic longitude coordinate of point, degrees.

** return value

Purpose: Calculates corrected geomagnetic coordinates

Included Commons:	Size (4 byte words)
J75	(300)

Entry points: CGMCS

Variables:

R*4	DX	R*4	DY	R*4	DZ	R*4	FF
R*4	FO	R*4	FX	R*4	FY	R*4	FZ
R*4	GG	R*4	GO	R*4	GX	R*4	GY
R*4	GZ	I*4	I	I*4	J	I*4	J1
I*4	JLP	R*4	XG	R*4	XX	R*4	YG
R*4	YY						

Arrays:

I*4	INDEX	(74)
R*4	TABLE1	(2, 91, 72)
R*4	TABLE2	(2, 91)
R*4	TABLEX	(2, 91)

Subroutines and Functions Referenced:

FOR$CLOSE FOR$OPEN

Module: CHANY

CALL: SUBROUTINE CHANY (FREQ,JUG,RLMT,RLAT,RLONG,MAN,F2C,RNOISE)

Call Arguments:

FREQ	Current operating frequency, MHz.
JUG	vestigial, not used
RLMT	local mean time at radar
RLAT	geographic latitude coordinate, degrees.
RLONG	geographic longitude coordinate, degrees.
MAN	man-made noise (as input 'NOISE')
F2C	F-layer critical frequency, MHz
** RNOISE	noise reference

** return value

Purpose: Calculates man-nade and galactic noise level at receiver

Included Commons:
no user defined commons

Entry points: CHANY

Variables:

R*4	ANOISE	R*4	ATNO	R*4	ATNU	R*4	ATNX
R*4	ATNY	R*4	ATNZ	R*4	F2C	R*4	FREQ
R*4	GNOISE	I*4	JK	I*4	JUG	I*4	KJ
I*4	MA	I*4	MAN	R*4	RKTB	R*4	RLAT
R*4	RLMT	R*4	RLONG	R*4	RNOISE	R*4	ROTHR
R*4	RRLONG	R*4	SNOISE	R*4	TM	R*4	XNOISE

Arrays:

R*4	XNINT	(4)

Subroutines and Functions Referenced:

GENFAM	R*4	MTH$ALOG	R*4	MTH$ALOG10	NOISY

Module: CLOCKS

CALL: FUNCTION CLOCKS (NY,NM,ND,NH,MN,NS,SLAT,SLON)

Call Arguments:

NY	Set year
NM	Set month
ND	Set day of the month (default is 15 in RADARC)
NH	Set Hour
MN	Set minute
NS	Set second
SLAT	geographic latitude of point of interest, degrees.
SLON	geographic longitude of point of interest, degrees.

** return value

Purpose: Determines various time parameters. Call arguments 'set' the clock, while entry point selection determines calculated parameter. Entry point CGMTIM used to get corrected geomagnetic time.

Included Commons:	Size (4 byte words)
BRILIG	(52)
WABE	(96)

Entry points:

R*4	CGMTIM	R*4	CLOCKS	R*4	DIPTIM	R*4	SUNTIM
R*4	TWOTIM						

Variables:

I*4	MN	I*4	MODE	I*4	ND	I*4	NH
I*4	NM	I*4	NS	I*4	NY	R*4	SLAT
R*4	SLON						

Arrays:

R*4	CD	(24)
I*4	NTIME	(9)
R*4	TIME	(4)

Subroutines and Functions Referenced:

GIMBAL	GYRE	JULIAN

Module: CORDY

CALL: SUBROUTINE CORDY (GCD,BR,X2,Y2,X,Y)

Call Arguments:

GCD		Great circle distance, radians
BR		Azimuth of interest , radians
X2		geographic latitude coordinate of the first point, radians
Y2		geographic west longitude of the first point, radians
**	X	geographic latitude coordinate of the second point, radians
**	Y	geographic west longitude of the second point, radians

** return value

Purpose: Calculates latitude and longitude of the landing point of an arc given the origination, length, and direction.

Included Commons:	Size (4 byte words)
DAT	(192)

Entry points: CORDY

Variables:

R*4	AK	R*4	BK	R*4	BR	R*4	C180
R*4	C360	R*4	CK	R*4	DF	R*4	DK
R*4	EEK	R*4	EK	R*4	GCD	R*4	GLG
R*4	GLT	R*4	RZ	R*4	S	R*4	X
R*4	X1	R*4	X2	R*4	Y	R*4	Y1
R*4	Y2						

Arrays:

R*4	AMON	(12)
R*4	SUN	(2, 12)

Subroutines and Functions Referenced:

R*4	MTH$ACOS	R*4	MTH$COS	R*4	MTH$SIGN	R*4	MTH$SI

Module: COSD

CALL: SUBROUTINE COSD (PT1,TT1,PT2,TT2,GA,CA)

Call Arguments:

PT1	Latitude of point a on sphere in degrees.
TT1	Longitude of point a on sphere in degrees.
PT2	Latitude of point b on sphere in degrees.
TT2	Longitude of point b on sphere in degrees.
** GA	Great circle distance between points a and b, radians
** CA	The cosine of GA

** return value

Purpose: calculates distance between two points on a sphere

Included Commons:	Size (4 byte words)
DAT	(192)

Entry points: COSD

Variables:

R*4	C1	R*4	C2	R*4	CA	R*4	CT
R*4	DEG	R*4	DT	R*4	EARTHR	R*4	GA
R*4	GMLAT	R*4	GMLON	R*4	P1	R*4	P2
R*4	PI	R*4	PID2	R*4	PIT2	R*4	PT1
R*4	PT2	R*4	RAD	R*4	S1	R*4	S2
R*4	TT1	R*4	TT2				

Arrays:

R*4	AMON	(12)
R*4	DUM	(4)
R*4	DUMM	(24)

Subroutines and Functions Referenced:

R*4	MTH$ACOS	R*4	MTH$COS	R*4	MTH$SIN

Module: CPTERP

CALL: SUBROUTINE CPTERP

Purpose: Sets indicies for plot cusp inserts

Included Commons:	Size (4 byte words)
CPTRP	(28)
CUSP	(1120)
INP	(72)
MIMSY	(2520)
PLT	(5080)
PLTAB	(11992)

Entry points: CPTERP

Variables:

R*4	AZMTH	R*4	GMT	I*4	IC	I*4	ICDF
I*4	ICFR	I*4	ICNR	I*4	ICP	I*4	ICTMP
I*4	IEXD	I*4	IGND	I*4	INR	I*4	IREFF
I*4	ISNR	I*4	ITMP	I*4	JFR	I*4	JNR
I*4	L	I*4	LK	I*4	M	I*4	MAN
I*4	MCP	I*4	MCR	I*4	METH	I*4	METHOD
I*4	MONS	I*4	MSNR	R*4	SSN	R*4	X1
R*4	Y1						

Arrays:

R*4	ALOOK	(6)
R*4	AMPCP	(4, 10)
R*4	DELCP	(4, 10)
R*4	FVCP	(4, 10)
I*4	IAMP	(8, 45)
I*4	IAMPCP	(4, 10)
I*4	IDIST	(8, 45)
I*4	IDLAY	(8, 45)
I*4	IDLYCP	(4, 10)
I*4	IDSTCP	(4, 10)
I*4	ILAY10	(45, 10)
I*4	ILAYER	(180)
I*4	ILY	(4, 10)
I*4	JNUM	(10)
I*4	JS	(4, 45)
I*4	LANG	(333, 3)

Module: CUSPFV

CALL: SUBROUTINE CUSPFV

Purpose: Computes values of the frequency/height parameters about the cusp and puts in reasonably smooth values that resemble those scaled from actual ionograms.

Included Commons:	Size (4 byte words)
CUSP	(1280)
ION	(436)

Entry points: CUSPFV

Variables:

R*4	FV	I*4	I	I*4	IFX	I*4	JCP
I*4	JDIN	I*4	JL	I*4	K3	I*4	KCP

Arrays:

R*4	AMPCP	(4, 10)
R*4	DELCP	(4, 10)
R*4	FI	(10, 3)
R*4	FREL	(15)
R*4	FVCP	(4, 10)
R*4	HI	(10, 3)
I*4	IAMPCP	(4, 10)
I*4	IDLYCP	(4, 10)
I*4	IDSTCP	(4, 10)
I*4	IFV	(4, 10)
I*4	ILY	(4, 10)
R*4	YI	(10, 3)

Module: CUSPIN

CALL: SUBROUTINE CUSPIN

Purpose: Calculates angles for the modified cusp values.

Included Commons:	Size (4 byte words)
APLT	(4)
CPTEST	(120)
CUSP	(1280)
DAT	(192)
HGH	(28800)
ION	(436)

Entry points: CUSPIN

Variables:

R*4	AK	R*4	BK	R*4	C180	R*4	C360
R*4	CDEL	R*4	CK	R*4	DK	R*4	EEK
R*4	EK	R*4	FREQ	R*4	FVTEST	R*4	GLG
R*4	GLT	I*4	I	I*4	IFX	I*4	J
I*4	JDIN	I*4	JL	I*4	JSTART	I*4	JSTOP
I*4	K3	I*4	KCP	I*4	N1	I*4	N2
I*4	NBLANK	I*4	NE	R*4	PI2	R*4	RZ

Arrays:

R*4	AFAC	(240, 10)
R*4	AMON	(12)
R*4	AMPCP	(4, 10)
R*4	DELCP	(4, 10)
R*4	FI	(10, 3)
R*4	FREL	(15)
R*4	FVCP	(4, 10)
R*4	HI	(10, 3)
R*4	HPRIM	(240, 10)
R*4	HTRUE	(240, 10)
I*4	IAMPCP	(4, 10)
I*4	IDLYCP	(4, 10)
I*4	IDSTCP	(4, 10)
I*4	IFV	(4, 10)
I*4	ILY	(4, 10)
I*4	JNUMM	(3, 10)
R*4	SUN	(2, 12)

Subroutines and Functions Referenced:

R*4	MTH$ACOS	R*4	MTH$SQRT

Module: CUSPSG

CALL: SUBROUTINE CUSPSG

Purpose: Calculates ray sets in the cusp region between regular layers

Included Commons:	Size (4 byte words)
ANT	(368)
APLT	(56)
CINI	(640)
CPTRP	(28)
CPTEST	(3000)
CUSP	(1600)
DAT	(192)
FOLO	(5040)
GEOG	(280)
GROUND	(720)
HGH	(28800)
ILOS	(2880)
INP	(92)
ION	(368)
LUNITS	(48)
MIMSY	(2520)
PLT	(3640)
RADR	(24)
TTSIZE	(180)

Entry points: CUSPSG

Variables:

R*4	ABSB	R*4	ADEL	R*4	ADEV	R*4	ADJ
R*4	AK	R*4	AMPANT	R*4	ANGDEL	R*4	ANOISE
R*4	ARAD	R*4	AREA	R*4	AZMTH	R*4	BK
R*4	BWIDTH	R*4	C180	R*4	C360	R*4	CK
R*4	DEL	R*4	DELAY	R*4	DELINC	R*4	DELPI
R*4	DK	R*4	EEK	R*4	EK	R*4	FCSQ
R*4	FNOISE	R*4	FREQ	R*4	FSQ	R*4	FV
R*4	GAIN	R*4	GDR	R*4	GLG	R*4	GLT
R*4	GMT	R*4	GRDLOS	R*4	HANG	R*4	HP
R*4	HT	R*4	HWIDTH	I*4	I	I*4	IADEL
I*4	IANG	I*4	IANT	I*4	IAZMTH	I*4	ICFR
I*4	ICNR	I*4	ICP	I*4	IDEL	I*4	IE
I*4	IEXD	I*4	IFR	I*4	IGND	I*4	IMONS
I*4	IPWUS	I*4	ISNR	I*4	ISSN	I*4	IT
I*4	JCUSP	I*4	JDIN	I*4	JFR	I*4	JHOP
I*4	JJ	I*4	JNR	I*4	K3	I*4	KHOP

Arrays:

R*4	ABIY	(10)
R*4	ADV	(4, 45)
R*4	AFAC	(240, 10)
R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	AMPCP	(4, 10)
R*4	ANDV	(4, 45)
R*4	AOF	(4, 45)
R*4	ARF	(4, 45)
R*4	BC	(10)
R*4	CLAT	(10)

CUSPSG (cont.)

```
R*4   CLCK          (10)
R*4   CLONG         (10)
R*4   CNRCP         (4, 10)
R*4   DELCP         (4, 10)
R*4   DELH          (10, 45)
R*4   DELI          (10, 45)
R*4   FFAK          (2)
R*4   FI            (10, 3)
R*4   FVCP          (4, 10)
R*4   GDIST         (4, 10)
R*4   GLAT          (10)
R*4   GNDIST        (4, 45)
R*4   GNDLOS        (4, 45)
R*4   GRLOS         (45)
R*4   GY            (10)
R*4   HI            (10, 3)
R*4   HPP           (4, 45)
R*4   HPRIM         (240, 10)
R*4   HTRUE         (240, 10)
I*4   IAMPCP        (4, 10)
I*4   IDIST         (8, 45)
I*4   IDLAY         (8, 45)
I*4   IDLYCP        (4, 10)
I*4   IDSTCP        (4, 10)
```

Subroutines and Functions Referenced:

```
R*4  MTH$ALOG10      R*4  MTH$ASIN      R*4  MTH$COS      R*4  MTH$SQ
```

Module: DATIME

```
CALL: SUBROUTINE DATIME(DATETIME)

 Call Arguments:
  **  DATETIME    text string containing the date/time

  **  return value

 Purpose:    this routine gets a date/time string from the operating system to
             stamp the output.

 Included Commons:
  no user defined commons

 Entry points: DATIME

 Variables:
  CHAR   DATETIME     I*4    STATUS

 Subroutines and Functions Referenced:
  I*4  LIB$DATE_TIME         LIB$SIGNAL
```

Module: DIPOLE

CALL: SUBROUTINE DIPOLE (TG,PG,TM,PM)

Call Arguments:
  TG   Geographic latitude in degrees.
  PG   Geographic longitude in degrees.
 ** TM   Centered dipole latitude in degrees.
 ** PM   Centered dipole longitude in degrees.

 ** return value

Purpose: Converts from geographic coordinates to earth centered dipole system

Included Commons:	Size (4 byte words)
DAT	(192)

Entry points: DIPOLE

Variables:

R*4	A	R*4	DEG	R*4	EARTHR	R*4	GMLAT
R*4	GMLON	R*4	PG	R*4	PI	R*4	PID2
R*4	PIT2	R*4	PM	R*4	RAD	R*4	TG
R*4	TM						

Arrays:

R*4	AMON	(12)
R*4	DUM	(4)
R*4	DUMM	(24)
R*4	R	(3, 3)
R*4	XD	(3)
R*4	XG	(3)

Subroutines and Functions Referenced:

R*4	MTH$ASIN	R*4	MTH$ATAN2	R*4	MTH$COS	R*4	MTH$SI

Module: DTOG

CALL: COMPLEX FUNCTION DTOG(X,R)

Call Arguments:
  X   distance, radians
  R   rotation matrix from xfrg

 ** return value

Purpose: Computes complex function of three variables

Included Commons:

	Size (4 byte words)
CONTIG	(16)
SCR	(4)

Entry points: *8 DTOG   0-00000019 R*4 GTOD

Variables:

R*4	BA	R*4	CPB	R*4	CPD	R*4	CPG
R*4	CSC	R*4	CTD	R*4	CTG	I*4	I
I*4	K	I*4	MODE	R*4	PD	R*4	PG
R*4	PI	R*4	SPB	R*4	SPD	R*4	SPG
R*4	STD	R*4	STG	R*4	TD	R*4	TG
C*8	X	C*8	Y	C*8	Z		

Arrays:

@	R*4	R	(3, 3)
	R*4	XD	(3)
	R*4	XG	(3)

Subroutines and Functions Referenced:

R*4	MTH$ACOS	R*4	MTH$ATAN2	R*4	MTH$COS	R*4	MTH$SI

Module: EF1VAR

CALL: SUBROUTINE EF1VAR (CYCEN,II)

Call Arguments:
CYCEN   solar zenith angle, degrees
II   selected sample area

** return value

Purpose: Calculates E and F1-layers ionospheric variables,

Included Commons:	Size (4 byte words)
A11	(24)
DAT	(192)
IONE	(480)
GEOG	(388)
INP	(68)
ION	(436)
IONINP	(480)
ZENDAT	(80)

Entry points: EF1VAR

Variables:

R*4	AK	R*4	AZMTH	R*4	BETAE	R*4	BETAF1
R*4	BK	R*4	C180	R*4	C360	R*4	CK
R*4	CKC	R*4	COND	R*4	COSDI	R*4	COSZ
R*4	CYCEN	R*4	DK	R*4	EEK	R*4	EK
R*4	EPR	R*4	GLG	R*4	GLT	R*4	GMT
I*4	ICCP	I*4	IEXD	I*4	IFX	I*4	II
I*4	JDIM	I*4	JL	I*4	K3	I*4	MAN
I*4	METH	I*4	METHOD	I*4	MON	R*4	PI2
R*4	RZ	R*4	SSN	R*4	X1	R*4	Y1
R*4	Z	R*4	ZMAX				

Arrays:

R*4	ABIY	(10)
R*4	ACHI	(2, 12)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	ANEW	(3, 12)

Subroutines and Functions Referenced:

R*4	MTH$COS	R*4	MTH$SQRT	VERSY

Module: ERF1

CALL: REAL*16 FUNCTION ERF1(X)

Call Arguments:
  X   Probability

  ** return value

Purpose: calculates standard error function from probability X

Included Commons:
 no user defined commons

Entry points: *16 ERF1

Variables:

R*4	A1	R*4	A2	R*4	A3	R*4	A4
R*4	POLY	R*4	POLY4	R*4	X		

Module: ESCON

```
CALL:   SUBROUTINE ESCON(FREQ,XNHP,VHIGHT,PAMAX,PA,
     1                  LAYER,RANGE,AVAIL,PES,PESM,ESD)
```

Call Arguments:

FREQ	Current operating frequency
XNHP	Number of hops
VHIGHT	Virtual height this rayset
PAMAX	best availability (so far)
PA	availability
LAYER	ionospheric layer character ('ES','F2','F1',OR 'E')
RANGE	ground range to end of hop
AVAIL	calculated availability including E_s
PES	Prob that freq < esd for es layer
PESM	Prob that freq > esd for all other layer
ESD	FoEs*sec(PHI); phi depends on layer

** return values

Purpose: This routine adds E_s probability to availability calculations.

Included Commons:	Size (4 byte words)
MUFS	(1044)
ES	(160)

Entry points: ESCON

Variables:

R*4	AVAIL	R*4	BETA	R*4	CB	R*4	ESD
R*4	FREQ	R*4	HE	R*4	HF1	CHAR	LAYER
I*4	MODMUF	R*4	PA	R*4	PAMAX	R*4	PES
R*4	PESM	R*4	PHE	R*4	PHES	R*4	PHF
R*4	PHF1	R*4	RANGE	R*4	RATE	R*4	RATES
R*4	RATF1	R*4	RATF2	R*4	RE	R*4	SB
R*4	VHIGHT	R*4	XNHP				

Arrays:

R*4	AFMUF	(4)
R*4	ALLMUF	(24)
R*4	ANGMUF	(24)
R*4	DELMUF	(4)
R*4	EMUF	(24)
R*4	ESMUF	(24)
R*4	F1MUF	(24)
R*4	F2MUF	(24)
R*4	FOT	(24)
R*4	FS	(3, 10)
R*4	FVMUF	(4)
R*4	HPF	(24)
R*4	HPMUF	(4)
R*4	HS	(10)
R*4	HTMUF	(4)
I*4	NHOPMF	(4)
R*4	SIGL	(4)
R*4	SIGU	(4)
R*4	XLUF	(24)
R*4	YFOT	(4)
R*4	YHPF	(4)
R*4	YMUF	(4)

ESCON (cont.)

Subroutines and Functions Referenced:

```
R*4  MTH$ASIN          R*4  MTH$ATAN          R*4  MTH$COS          R*4  MTH$SI
```

Module: ESDIS

CALL: SUBROUTINE ESDIS (ESMUF,FREQ,KSIDE,IT,SIG)

Call Arguments:

ESMUF	E_s layer MUF
FREQ	current operating frequency
KSIDE	hop number
IT	Greenwhich mean time
SIG	probability that freq < esmuf

** return value

Purpose: Calculates probability of sporadic-E modes and determine losses

Included Commons:	Size (4 byte words)
ES	(120)

Entry points: ESDIS

Variables:

R*4	ESMUF	R*4	FAT	R*4	FREQ	I*4	IT
I*4	KSIDE	R*4	SC1	R*4	SC2	R*4	SC3
R*4	SIG						

Arrays:

R*4	FOES	(10, 3)

Module: ESIND

CALL: SUBROUTINE ESIND (GMT)

Call Arguments:
GMT   Greenwhich Mean Time

** returned value

Purpose: Calculates the sporadic-E MUF by a call to VERSY. Data for the E_s-layer was calculated in REDMAP.

Included Commons:	Size (4 byte words)
All	(24)
ES	(160)
GEOG	(336)
IONINP	(480)

Entry points: ESIND

Variables:

R*4	GMT	I*4	ID	I*4	II

Arrays:

R*4	ABIY	(10)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	FESINP	(10, 3)
R*4	FIINP	(10, 3)
R*4	FOES	(10, 3)
R*4	GAMMA	(6)
R*4	GLAT	(10)
R*4	GY	(10)
R*4	HIINP	(10, 3)
R*4	HS	(10)
R*4	PSC	(4)
R*4	RAT	(10)
R*4	RD	(10)
R*4	YIINP	(10, 3)

Subroutines and Functions Referenced:
VERSY

Module: ESSNR

CALL: SUBROUTINE ESSNR (IESFLG)

Call Arguments:
IESFLG Flag to use(+)/not use(0) E_s layer

** return value

Purpose: determines raysets and all variables used in RADAR equation associated with sporadic-E modes.

Included Commons:	Size (4 byte words)
ANT	(368)
APLT	(60)
DAT	(192)
ES	(160)
FOLO	(9360)
GEOG	(348)
HOP	(4)
ILOS	(2880)
INP	(92)
ION	(436)
LUNITS	(48)
PLT	(3640)
RADR	(16)
TIME	(23)
TTSIZE	(180)
AVAIL_INP	(112)
MIMSY	(2520)
RAD2AVA	(40)
PIR	(24)
OVAL	(8)

Entry points: ESSNR

Variables:

R*4	ABPS1	R*4	ABSA1	R*4	ABSB	R*4	ADEL
R*4	ADJ	R*4	AK	R*4	AMPANT	R*4	ANOISE
R*4	AREA	R*4	AREF	R*4	AZMTH	R*4	AZRAD
R*4	BANDW	R*4	BANDWO	R*4	BK	R*4	BMONS
R*4	BWIDTH	R*4	C180	R*4	C360	R*4	CIT
R*4	CK	R*4	CKC	R*4	COND	CHAR	DATETIME
R*4	DEL	R*4	DELAY	R*4	DELINC	R*4	DINC
R*4	DK	R*4	DUM	R*4	DUMMY	R*4	DWR
R*4	ECLUT	R*4	ECLUTO	R*4	EEK	R*4	EK
R*4	EPR	R*4	ETA	R*4	FCLUT	R*4	FCLUTO
R*4	FCLUT2	R*4	FNOISE	R*4	FREQ	R*4	GAIN
R*4	GCD	R*4	GDR	R*4	GLG	R*4	GMT
R*4	GNDLOS	R*4	GT	R*4	HANG	R*4	HP
R*4	HWIDTH	I*4	I	I*4	IANT	I*4	IAZMTH
I*4	IBCL	I*4	IDUM	I*4	IES	I*4	IESFLG

Arrays:

R*4	ABIY	(10)
R*4	ADV	(4, 45)
R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	ANDV	(4, 45)

ESSNR (cont.)

```
R*4  AOF              (4, 45)
R*4  ARF              (4, 45)
R*4  CLAT             (10)
R*4  CLCK             (10)
R*4  CLONG            (10)
R*4  CNR              (8, 45)
R*4  CPDB             (8, 45)
R*4  DELH             (10, 45)
R*4  DELI             (10, 45)
R*4  F1C              (10)
R*4  F2C              (10)
R*4  FEC              (10)
R*4  FOES             (10, 3)
R*4  FREL             (15)
R*4  GDIST            (4, 45)
R*4  GLAT             (10)
```

Subroutines and Functions Referenced:

```
     ABILITY_V3          CORDY          R*4  GLOSS          R*4  MTH$AL
```

Module: ESTERP

CALL: SUBROUTINE ESTERP

Purpose: Sets indicies for sporadic E-layer printer plots

Included Commons:	Size (4 byte words)
APLT	(52)
ES	(160)
ESTAB	(3996)
FOLO	(5040)
HOP	(4)
ILOS	(2880)
INP	(72)
PLT	(5080)
PLTAB	(11992)

Entry points: ESTERP

Variables:

R*4	AZMTH	R*4	BMONS	R*4	FNOISE	R*4	FREQ
R*4	GMT	I*4	I	I*4	IANT	I*4	IAZMTH
I*4	IC	I*4	ICDF	I*4	ICFR	I*4	ICNR
I*4	IEXD	I*4	IFR	I*4	IGND	I*4	INOS
I*4	IPWUS	I*4	IREFF	I*4	ISNR	I*4	ISSN
I*4	ISTAR	I*4	IT	I*4	JFR	I*4	JNR
I*4	KMAX	I*4	L	I*4	LIMHOP	I*4	MAN
I*4	METH	I*4	METHOD	I*4	MONS	I*4	MSNR
R*4	PWR	R*4	SSN	R*4	X1	R*4	X2
R*4	Y1	R*4	Y2				

Arrays:

R*4	ADV	(4, 45)
R*4	ALOOK	(6)
R*4	AMP	(8, 45)
R*4	ANDV	(4, 45)
R*4	AOF	(4, 45)
R*4	ARF	(4, 45)
R*4	DELH	(10, 45)
R*4	DELI	(10, 45)
R*4	FOES	(10, 3)
R*4	HS	(10)
I*4	IAMP	(8, 45)

Module: F1COF

CALL: SUBROUTINE F1COF

Purpose: Determines data base and calculates F1-layer parameters from monthly numerical coefficients

Included Commons:	Size (4 byte words)
FONE	(480)
INP	(68)
LUNITS	(48)

Entry points: F1COF

Variables:

R*4	AZMTH	R*4	D2R	R*4	GMT	I*4	I
I*4	ICCP	I*4	IEXD	I*4	J	I*4	K
I*4	L	I*4	LANT	I*4	LCON	I*4	LGEO
I*4	LIONO	I*4	LMAP	I*4	LNOISE	I*4	LOUT1
I*4	LOUT2	I*4	LOUT3	I*4	LSCRT	I*4	LSEMI
I*4	LTAR	I*4	M	I*4	MAN	I*4	METH
I*4	METHOD	I*4	MONS	I*4	MONTH	R*4	SSN
R*4	TM	R*4	X1	R*4	Y1		

Arrays:

R*4	ABC	(3)
R*4	ABCR	(3)
R*4	ACHI	(2, 12)
R*4	ALOOK	(6)
R*4	ANEW	(3, 12)
R*4	BCHI	(2, 12)
R*4	BNEW	(3, 12)
R*4	C	(3)
R*4	DE	(2)
R*4	DER	(2)
R*4	FF	(3, 7)
R*4	GG	(3, 7)
R*4	HH	(2, 7)
R*4	JJ	(2, 7)
R*4	S	(3)
R*4	UVW	(3)
R*4	XY	(2)

Subroutines and Functions Referenced:

R*4	MTH$COS	R*4	MTH$SIN

Module: F2VAR

CALL: SUBROUTINE F2VAR

Purpose: Uses F2-layer numerical maps calculated by VERSY.

Included Commons:	Size (4 byte words)
A11	(24)
DAT	(192)
GEOG	(336)
ION	(436)
INP	(68)
IONINP	(480)
OVAL	(8)
ZENDAT	(80)

Entry points: F2VAR

Variables:

R*4	AK	R*4	AZMTH	R*4	BK	R*4	C180
R*4	C360	R*4	CK	R*4	DELZ	R*4	DH
R*4	DHN	R*4	DK	R*4	EC	R*4	EEK
R*4	EK	R*4	FC	R*4	FC1	R*4	FCEC
R*4	FFEC	R*4	GLG	R*4	GLT	R*4	GMT
R*4	HM	R*4	HN	I*4	ICCP	I*4	IEXD
I*4	IFX	I*4	II	I*4	JDIM	I*4	JL
I*4	K3	I*4	MAN	I*4	METH	I*4	METHOD
I*4	MONS	I*4	MYR	R*4	PI2	R*4	RET
R*4	RFN	R*4	RFT	R*4	RZ	R*4	SSN
R*4	SZ	R*4	X1	R*4	XF1	R*4	XKP
R*4	Y1	R*4	Y1MAX	R*4	YM	R*4	YN
R*4	Z	R*4	ZMAX	R*4	ZN		

Arrays:

R*4	ABIY	(10)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	F1C	(10)
R*4	F2C	(10)

Subroutines and Functions Referenced:

R*4	MTH$ALOG	POLARC	VERSY

Module: FKEP

```
CALL: FUNCTION FKEP(M,E)

Call Arguments:
  M     mean anomoly
  E     eccentricity

 **  return value

Purpose:   Calculates true anomaly

Included Commons:
 no user defined commons

Entry points: FKEP

Variables:
 R*4    C4O3          R*4    CEM           R*4    E             R*4    M
 R*4    SEM

Subroutines and Functions Referenced:
 R*4   MTH$COS          R*4  MTH$SIN
```

Module: FOBBY

CALL: SUBROUTINE FOBBY (FMAXX)

Call Arguments:
FMAXX Maximum frequency supported, MHz.

** return value

Purpose: Generates the reflectrix and determines oblique frequencies.

Included Commons:	Size (4 byte words)
APLT	(52)
A2	(432000)
DAT	(192)
FOLO	(5040)
HGH	(28800)
INP	(68)
ION	(436)
LUNITS	(48)
RADR	(16)

Entry points: FOBBY

Variables:

R*4	AI	R*4	AK	R*4	AZMTH	R*4	BK
R*4	BWIDTH	R*4	C180	R*4	C360	R*4	CK
R*4	COSPHE	R*4	DEL	R*4	DELINC	R*4	DK
R*4	EEK	R*4	EK	R*4	FMAXX	R*4	FNOISE
R*4	FREQ	R*4	FV	R*4	GLG	R*4	GLT
R*4	GMT	I*4	I	I*4	IANT	I*4	IAZMTH
I*4	ICCP	I*4	IEXD	I*4	IFR	I*4	IFX
I*4	IMONS	I*4	IPWUS	I*4	ISSN	I*4	IT
I*4	J	I*4	JDIN	I*4	JL	I*4	K
I*4	KFX	I*4	KJ	I*4	KK	I*4	KL
I*4	KMAX	I*4	KMN	I*4	KND	I*4	KX
I*4	KY	I*4	KZ	I*4	L	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	MAN
I*4	METH	I*4	METHOD	I*4	MONS	I*4	N
R*4	PHE	R*4	PI2	R*4	PWID	R*4	PWP
R*4	PWR	R*4	R	R*4	RCOSD	R*4	SSN
R*4	X1	R*4	X2	R*4	XJ	R*4	Y1
R*4	Y2						

Arrays:

R*4	LOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	DELH	(10, 45)
R*4	DELI	(10, 45)
R*4	DFR	(240, 10)
R*4	FI	(10, 3)
R*4	FOB	(240, 450)
R*4	FOBMAX	(10)
R*4	FREL	(15)
R*4	HI	(10, 3)
R*4	HPRIM	(240, 10)
R*4	HTRUE	(240, 10)

FOBBY (cont.)

```
R*4  SUN        (2, 12)
R*4  YI         (10, 3)
```

Module: fpok

CALL: subroutine fpok(tg,pg,xkp,une)

Call Arguments:

TG	geographic latitude, radians
PG	geographic longitude, radians
XKP	planetary magnetic index (input as 'KP')
UNE	3 component array describing local magnetic field

** return value

Purpose: Determines probability of spread Doppler

Included Commons:	Size (4 byte words)
POK	(84)
SOL	(56)
VEL	(16)
VV	(16)
DOP	(16)
PIR	(24)
TRACE	(20)
SUM	(16)

Entry points: FPOK

Variables:

R*4	BETAE	R*4	BETAF	R*4	CCLT	R*4	CLAT
R*4	CLG	R*4	CLON	R*4	CLT	R*4	CSDC
R*4	CSDY2	R*4	CSLO	R*4	CZ	R*4	CZ1
R*4	CZ2	R*4	CZT	R*4	D15	R*4	D2R
R*4	DB	R*4	DEG	R*4	DEL	R*4	DIP
R*4	DOPLE	R*4	DOPLF	R*4	EPSLON	R*4	FPOX
R*4	GDEC	R*4	GHRMT	R*4	GLAG	R*4	GLAT
R*4	GLON	I*4	ITRC	I*4	KLMT	I*4	LAYER
R*4	ORTANG	R*4	PG	R*4	PI	R*4	PI2
R*4	PINC	R*4	PROBABLY_F	R*4	PROBABLY_P	R*4	PROBE
R*4	PROBF	R*4	PVBAR	R*4	R2D	R*4	SCLT
R*4	SDEC	R*4	SGLO	R*4	SQR2	R*4	SSDC
R*4	SSLAT	R*4	SSLON	R*4	TG	R*4	TIME
R*4	TOA	R*4	UT	R*4	VAL	R*4	VE
R*4	VELEE	R*4	VELEN	R*4	VELFE	R*4	VELFN
R*4	VF	R*4	VSE	R*4	VSF	R*4	XKP

Arrays:

	R*4	POS	(3)
	R*4	RAY	(3)
	R*4	SUN	(14)
@	R*4	UNE	(3)

Subroutines and Functions Referenced:

	CGMCS	R*4	MTH$ACOS	R*4	MTH$ALOG10	R*4	MTH$CO
R*4	PFIR						

Module: GAUSS

CALL: FUNCTICN GAUSS (C)

Call Arguments:
  C   Deviation from median in standard units

  ** return value

Purpose: calculates the probability associated with a given deviation

Included Commons:
 no user defined commons

Entry points: GAUSS

Variables:

R*4	B	R*4	C	I*4	I	R*4	SUM
R*4	UPLIM	R*4	Y				

Arrays:

R*4	A	(8)
R*4	H	(8)

Subroutines and Functions Referenced:
 R*4 MTH$EXP

Module: GENFAM

```
CALL: SUBROUTINE GENFAM (Y2,IBLK,FREQ,Z,FA)

Call Arguments:
  Y2    real variable containing the sign of the latitude
  IBLK      Index to coefficient array (see noisy)
  FREQ      current operating frequency
  Z     atmospheric noise at 1 MHz calculated by noisy, dB kTb
 **  FA       atmospheric noise with frequency dependence, dBw

 **  return value

Purpose:   Determines frequency dependence of atmospheric noise

Included Commons:              Size (4 byte words)
 DUD                             (    1248)

Entry points: GENFAM

Variables:
 R*4    CZ            R*4    FA            R*4    FREQ          I*4    I
 I*4    IBK           I*4    IBLK          I*4    KOP           R*4    PX
 R*4    PZ            R*4    U             R*4    U1            R*4    X
 R*4    Y2            R*4    Z

Arrays:
 R*4  FAM            (14, 12)
 R*4  SYS            (9, 16)
 R*4  V              (5)

Subroutines and Functions Referenced:
 R*4  MTH$ALOG
```

Module: GENION

CALL: SUBROUTINE GENION

Purpose: Integrates the true height electron density profiles to obtain a virtual height profile that will be used for all calculations from this point.

Included Commons:	Size (4 byte words)
A2	(432000)
HGH	(28800)
ION	(436)

Entry points: GENION

Variables:

R*4	FNYI	R*4	FR	R*4	FX	R*4	HP
R*4	HR	R*4	HRMZ	I*4	I	I*4	IFX
I*4	IG	I*4	JDIN	I*4	JF	I*4	JFD
I*4	JL	I*4	K	I*4	KFX	R*4	MXP
R*4	MYP	I*4	NPL	I*4	NT	R*4	TWDIV
R*4	XNPL	R*4	YSQ	R*4	ZG	R*4	ZI

Arrays:

R*4	AFAC	(240, 10)
R*4	FI	(10, 3)
R*4	FNSQ	(200, 10)
R*4	FOB	(108000)
R*4	FREL	(15)
R*4	HB	(10)
R*4	HI	(10, 3)
R*4	HPHAS	(240, 10)
R*4	HPRIM	(240, 10)
R*4	HTP	(10)
R*4	WT	(20)
R*4	XT	(20)
R*4	YI	(10, 3)

Subroutines and Functions Referenced:

R*4	MTH$SQRT	VPLOT	R*4	XLIN

Module: GEOM

CALL: SUBROUTINE GEOM (ILOOK)

Call Arguments:
ILOOK index to sample area

** return value

Purpose: Calculates geographical and geomagnetic parameters.

Included Commons:	Size (4 byte words)
A11	(24)
DAT	(192)
GEOG	(388)
ION	(436)
INP	(68)

Entry points: GEOM

Variables:

R*4	AK	R*4	AZMTH	R*4	BK	R*4	BTRY
R*4	C180	R*4	C360	R*4	CENLAT	R*4	CENLG
R*4	CK	R*4	CKC	R*4	CLG	R*4	COND
R*4	DK	R*4	EEK	R*4	EK	R*4	EPR
R*4	GAT	R*4	GLG	R*4	GLT	R*4	GMT
I*4	ICCP	I*4	IEXD	I*4	IFX	I*4	II
I*4	ILOOK	I*4	IOP	I*4	JDIM	I*4	JL
I*4	K3	I*4	MAN	I*4	METH	I*4	METHOD
I*4	MONS	R*4	PI2	R*4	PP	R*4	RZ
R*4	SSN	R*4	WLD	R*4	X1	R*4	XX1
R*4	Y1	R*4	YY1				

Arrays:

R*4	ABIY	(10)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)
R*4	FREL	(15)
R*4	GAMMA	(6)
R*4	GLAT	(10)
R*4	GMDIP	(10)
R*4	GY	(10)

Subroutines and Functions Referenced:

CORDY	MAGVAR	I*4 MAP	R*4 MTH$AC

Module: GEOMAG

CALL: SUBROUTINE GEOMAG (XLAT,XLONG,GMLAT,GMLONG)

Call Arguments:

XLAT	geographic latitude coordinate, degrees.
XLONG	geographic longitude coordinate, degrees.
** GMLAT	geomagnetic latitude coordinate, degrees.
** GMLONG	geomagnetic longitude coordinate, degrees.

** return value

Purpose: Converts a point given in geographic coordinates to corresponding corrected geomagnetic coordinates

Included Commons:	Size (4 byte words)
TABLE	(51264)
LUNITS	(48)

Entry points: GEOMAG

Variables:

R*4	AA	R*4	AAORG	R*4	AORG	R*4	B
R*4	BB	R*4	BETA	R*4	C	R*4	CC
R*4	D	R*4	DD	R*4	FA	R*4	FB
R*4	FPMD	CHAR	GFILE	R*4	GMLAT	R*4	GMLNN
R*4	GMLNS	R*4	GMLONG	R*4	GMLTN	R*4	GMLTS
I*4	I	I*4	IM	I*4	IMP	I*4	IP
I*4	IT	I*4	ITP	I*4	J	I*4	JLN
I*4	JREAD	I*4	K	I*4	L	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	R*4	P
R*4	PHI	R*4	Q	R*4	X	R*4	XLAT
R*4	XLONG	R*4	Y				

Arrays:

R*4	A	(2, 72, 89)
I*4	IIM	(2)
I*4	IIT	(2)
R*4	XP	(2)
R*4	YP	(2)

Subroutines and Functions Referenced:

FOR$CLOSE	FOR$OPEN	R*4 MTH$AMOD	R*4 MTH$CO

Module: GIMBAL

CALL: SUBROUTINE GIMBAL (MODE)

Call Arguments:
  MODE   integer flag to identify desired value
            0 Sidereal time (sid) and apparent solar time (ast) only
            1 Sid,ast, and corrected geomagnetic time (cmt)
            2 Sid,ast, and centered dipole magnetic time (dmt)
            3 Sid,ast,cmt,dmt are all computed.

 ** return value

Purpose: Updates the solar emphemeris data computed by GYRE to sideral, corrected geomagnetic and earth centered dipole magnetic time

Included Commons:	Size (4 byte words)
BRILIG	(52)
RATHS	(80)
SLITHY	(44)
TOVES	(92)
WABE	(96)

Entry points: GIMBAL

Variables:

R*4	A	R*4	ALPHA	R*4	AS	R*4	B
R*4	CE	R*4	CM	R*4	CO	R*4	D
R*4	DBDT	R*4	DDDT	R*4	DELTA	R*4	DIP
R*4	DLDT	R*8	DP	R*4	DQDT	R*4	DRDT
R*4	DS	R*4	DT	R*4	DUDT	R*4	DVDT
R*4	DXDT	R*4	DYDT	R*4	DZDT	R*4	E
R*4	ED	R*4	GD	R*4	GM	R*4	HM
R*4	HN	R*4	HOUR	I*4	I	I*4	JD
I*4	K	I*4	L	I*4	M	I*4	MN
I*4	MODE	I*4	MODED	I*4	N1	I*4	ND
I*4	NH	I*4	NJ	I*4	NM	I*4	NS
I*4	NY	R*4	O	R*4	P	R*8	PD
R*8	PI	R*4	PM	R*4	PP	R*4	Q
R*4	R	R*4	SE	R*4	SG	R*4	SID
R*4	SM	R*4	SO	R*4	SOLONG	R*4	ST
R*4	SUN	R*4	T	R*4	T2	R*4	TD

Arrays:

R*4	PH	(14)
R*4	TIME	(4)

Subroutines and Functions Referenced:

COSD   DIPOLE   GEOMAG

Module: GLOSS

CALL: REAL FUNCTION GLOSS(RLAT, RLONG, DELTA)

Call Arguments:

```
RLAT      geographic latitude, degrees.
RLONG     geographic longitude, degrees.
DELTA     take-off angle, degrees.

**  return value
```

Purpose: Calculates the reflection loss per hop for multi-hop paths

Included Commons:	Size (4 byte words)
APLT	(4)

Entry points: GLOSS

Variables:

R*4	ALFA	R*4	ASIX	R*4	COSDSQ	R*4	DELTA
R*4	EPS	R*4	FREQ	I*4	ILAT	I*4	ILONG
R*4	RHO	R*4	RLAT	R*4	RLONG	R*4	SIG
R*4	SIND	R*4	SIND2	R*4	SIND4	R*4	SQRHO
R*4	SQZETA	R*4	TEMP	R*4	WKHSQ	R*4	WKVSQ
R*4	WLD	R*4	WLG	R*4	XW	R*4	ZETA

Subroutines and Functions Referenced:

I*4	MAP	R*4	MTH$ALOG	R*4	MTH$ASIN	R*4	MTH$AT
R*4	MTH$SQRT						

Module: GYRE

CALL: SUBROUTINE GYRE

Purpose: Computes solar ephemeris data of this time, in particular, right ascension, declination, and Greenwich SID time

Included Commons:	Size (4 byte words)
BRILIG	(52)
RATHS	(80)
SLITHY	(44)
TOVES	(92)

Entry points: GYRE

Variables:

R*4	A	R*4	B	R*4	CE	R*4	CM
R*4	CO	R*4	D	R*4	DBDT	R*4	DDDT
R*4	DLDT	R*8	DP	R*4	DQDT	R*4	DRDT
R*4	DT	R*4	DUDT	R*4	DVDT	R*4	DXDT
R*4	DYDT	R*4	DZDT	R*4	E	R*4	E2
R*4	E3	R*4	ED	R*4	HOUR	R*4	I
I*4	J	I*4	JD	I*4	K	I*4	KK
R*4	L	R*4	M	I*4	MN	I*4	N1
I*4	ND	I*4	NGM	I*4	NH	I*4	NJ
I*4	NM	I*4	NS	I*4	NY	R*4	O
R*4	P	R*8	PD	R*8	PI	R*4	Q
R*4	R	R*4	RH1	R*4	RH2	R*4	SE
R*4	SM	R*4	SO	R*4	T	R*4	T2
R*4	U	R*4	V	R*4	W	R*4	X
R*4	X1	R*4	X2	R*4	Y	R*4	Z

Arrays:

R*8	CX	(3)
R*4	EL	(23)
R*4	PCON	(17)
R*4	PH	(14)

Subroutines and Functions Referenced:

R*4	MTH$ATAN	R*4	MTH$ATAN2	R*4	MTH$COS	R*4	MTH$SI

Module: HEAD99

CALL: SUBROUTINE HEAD99

Purpose: Writes the binary header in the FOR099.DAT file. This scratch file is used by read99 and rea992 to generate combined raysets tables.

Included Commons:	Size (4 byte words)
APLT	(36)
INP	(88)
LUNITS	(48)
RADR	(12)

Entry points: HEAD99

Variables:

R*4	AZMTH	R*4	BMONS	R*4	BWIDTH	R*4	FREQ
R*4	FREQQ	R*4	GMT	I*4	IAZMTH	I*4	IEXD
I*4	IGND	I*4	ISNR	I*4	ISSN	I*4	IT
I*4	KMAX	I*4	LANT	I*4	LCON	I*4	LGEO
I*4	LIONO	I*4	LMAP	I*4	LNOISE	I*4	LOUT1
I*4	LOUT2	I*4	LOUT3	I*4	LSCRT	I*4	LSEMI
I*4	LTAR	I*4	MAN	I*4	METH	I*4	METHOD
I*4	MONS	I*4	NLAT	I*4	NLON	R*4	OTH
R*4	PKAVG	R*4	PWID	R*4	PWP	R*4	PWR
R*4	SSN	R*4	TAR	R*4	TARSIZ	R*4	TIMEIT
R*4	TIMLOG	R*4	TXLAT	R*4	TXLON	R*4	X1
R*4	X2	R*4	Y1	R*4	Y2		

Arrays:

R*4	ALOOK	(6)
I*4	NNLAT	(2)
I*4	NNLON	(2)

Subroutines and Functions Referenced:

R*4 MTH$ALOG10

Module: INLEC

CALL: SUBROUTINE INLEC (JL)

Call Arguments:
JL

** return value

Purpose: reads electron density profile or virtual heights(ionogram)

Included Commons:	Size (4 byte words)
A2	(432000)
HGH	(28800)
INP	(92)
LUNITS	(48)

Entry points: INLEC

Variables:

R*4	AZMTH	R*4	GMT	R*4	HANG	I*4	I
I*4	ID	I*4	IEXD	I*4	IGND	I*4	IK
I*4	IN	I*4	ISNR	I*4	IX	I*4	J
I*4	JL	I*4	K	I*4	L	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	M
I*4	MAN	I*4	METH	I*4	METHOD	I*4	MONS
I*4	N	R*4	OTH	R*4	PKAVG	R*4	SSN
R*4	TAR	R*4	TIMEIT	R*4	X1	R*4	Y1

Arrays:

R*4	AFAC	(240, 10)
R*4	ALOOK	(6)
R*4	FNSQ	(200, 10)
R*4	FOB	(108000)

Subroutines and Functions Referenced:
VPLOT

Module: INPUT

CALL: SUBROUTINE INPUT

Purpose: to read electron density information from a file

Included Commons:	Size (4 byte words)
ANT	(372)
APLT	(60)
DAT	(192)
ES	(160)
GEOG	(348)
INP	(92)
ION	(436)
LUNITS	(48)
RADR	(24)
SLS	(88)

Entry points: INPUT

Variables:

R*4	AK	R*4	ASKP	R*4	AZMTH	R*4	BK
R*4	BWIDTH	R*4	C180	R*4	C360	R*4	CK
R*4	CKC	R*4	COND	R*4	DELINC	R*4	DK
R*4	EEK	R*4	EK	R*4	EPR	R*4	FNOISE
R*4	FREQ	R*4	GAZM	R*4	GLG	R*4	GLT
R*4	GMT	R*4	HANG	R*4	HWIDTH	I*4	I
I*4	IA	I*4	IANT	I*4	IAZMTH	I*4	IEXD
I*4	IFR	I*4	IFX	I*4	IGND	I*4	IMONS
I*4	IPWUS	I*4	IQRT	I*4	ISNR	I*4	ISSN
I*4	IT	I*4	J	I*4	JDIM	I*4	JDIN
I*4	JL	I*4	K	I*4	KMAX	I*4	KX
I*4	KZ	I*4	LANT	I*4	LCON	I*4	LGEO
I*4	LIONO	I*4	LMAP	I*4	LNOISE	I*4	LOUT1
I*4	LOUT2	I*4	LOUT3	I*4	LSCRT	I*4	LSEMI
I*4	LTAR	I*4	MAN	I*4	METH	I*4	METHOD
I*4	MONS	R*4	OTH	R*4	PI2	R*4	PKAVG
R*4	PWID	R*4	PWP	R*4	PWR	R*4	RZ
R*4	SIGBAK	R*4	SKPSIG	R*4	SNOISE	R*4	SSN
R*4	TAR	R*4	TIMEIT	R*4	X1	R*4	X2
R*4	Y1	R*4	Y2				

Arrays:

R*4	ABIY	(10)
R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)
R*4	FFAK	(2)
R*4	FOES	(10, 3)
R*4	FREL	(15)
R*4	GLAT	(10)
R*4	GRLOS	(45)
R*4	GY	(10)
R*4	HE	(10)
R*4	HF1	(10)

INPUT (cont.)

```
 R*4  HF2            (10)
 R*4  HS             (10)
 I*4  ISCLS          (5, 2)
 I*4  ITIM           (5, 2)
 R*4  PSC            (4)
 R*4  RAT            (10)
 R*4  RD             (10)
 R*4  SUN            (2, 12)
 R*4  YME            (10)
 R*4  YMF1           (10)
 R*4  YMF2           (10)

Subroutines and Functions Referenced:
      INLEC             R*4  MTH$ALOG
```

Module: INTERP

CALL: SUBROUTINE INTERP

Purpose: Sets indicies for regular layer printer plots (E,F1, and F2)

Included Commons:	Size (4 byte words)
APLT	(52)
CPTRP	(28)
CPTEST	(120)
CUSP	(960)
DAT	(192)
FOLO	(5040)
HOP	(4)
INP	(72)
MIMSY	(2520)
PLT	(5080)
PLTAB	(11992)

Entry points: INTERP

Variables:

R*4	AK	R*4	AZMTH	R*4	BK	R*4	BMONS
R*4	C180	R*4	C360	R*4	CK	R*4	DK
R*4	EEK	R*4	EK	R*4	FNOISE	R*4	FREQ
R*4	GLG	R*4	GLT	R*4	GMT	I*4	I
I*4	IANT	I*4	IAZMTH	I*4	IC	I*4	ICDF
I*4	ICFR	I*4	ICNR	I*4	ICP	I*4	ICP1
I*4	ICP3	I*4	IEXD	I*4	IFR	I*4	IGND
I*4	IPWUS	I*4	IREFF	I*4	ISNR	I*4	ISSN
I*4	IT	I*4	JFR	I*4	JNR	I*4	KMAX
I*4	LHOP	I*4	LIMHOP	I*4	M	I*4	M1
I*4	MAN	I*4	MCP	I*4	METH	I*4	METHOD
I*4	MONS	I*4	MSNR	R*4	PI2	R*4	PWR
R*4	RZ	R*4	SSN	R*4	X1	R*4	X2
R*4	Y1	R*4	Y2				

Arrays:

R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	AMPCP	(4, 10)
R*4	DELCP	(4, 10)

Subroutines and Functions Referenced:

CPTERP CUSPSG SETCP

Module: IONGEN

CALL: SUBROUTINE IONGEN

Purpose: Retrieves the input data supplied by the user and develops the ionospheric parameters for the three layers (E,F1 and F2).

Included Commons:	Size (4 byte words)
APLT	(60)
DAT	(180)
GEOG	(336)
INP	(92)
ION	(436)
LUNITS	(48)
RADR	(24)

Entry points: IONGEN

Variables:

R*4	AK	R*4	AZMTH	R*4	BK	R*4	BWIDTH
R*4	CK	R*4	DELINC	R*4	DK	R*4	EEK
R*4	EK	R*4	FNOISE	R*4	FREQ	R*4	GLG
R*4	GLT	R*4	GMT	R*4	HANG	I*4	IANT
I*4	IAZ	I*4	IAZMTH	I*4	IEXD	I*4	IFR
I*4	IFX	I*4	IGND	I*4	ILOOK	I*4	IMONS
I*4	IPWUS	I*4	IQRT	I*4	ISNR	I*4	ISSN
I*4	IT	I*4	ITSKP	I*4	ITSTP	I*4	ITSTR
I*4	JDIM	I*4	JL	I*4	K3	I*4	KMAX
I*4	LANT	I*4	LCON	I*4	LGEO	I*4	LIONO
I*4	LMAP	I*4	LNOISE	I*4	LOUT1	I*4	LOUT2
I*4	LOUT3	I*4	LSCRT	I*4	LSEMI	I*4	LTAR
I*4	MAN	I*4	METH	I*4	METHOD	I*4	MONS
I*4	NEWNOISE	R*4	OTH	R*4	PI2	R*4	PKAVG
R*4	PWID	R*4	PWP	R*4	PWR	R*4	SNOISE
R*4	SSN	R*4	TAR	R*4	TIMEIT	R*4	X1
R*4	X2	R*4	Y1	R*4	Y2		

Arrays:

R*4	ABIY	(10)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	CLAT	(10)
R*4	CLCK	(10)

Subroutines and Functions Referenced:

BAKSCT	ESIND	F1COF	F2VAR
READIN	REDMAP	TIMVAR	VERTIM

Module: JULIAN

CALL: FUNCTION JULIAN(NY,MN,ND)

Call Arguments:
  NY   2-digit year
  MN   2-digit month
  ND   2-digit day of the month

 ** return value

Purpose: Converts Gregorian calendar date to Julian day.

Included Commons:
 no user defined commons

Entry points: JULIAN

Variables:

I*4	LY	I*4	MN	I*4	ND	I*4	NY

Arrays:

I*4	MON	(12)

Module: LECDEN

CALL: SUBROUTINE LECDEN

Purpose: Calculates the electron density profiles (parabolic layers) from the parameters read in by INPUT.

Included Commons:	Size (4 byte words)
A2	(432000)
HGH	(28800)
INP	(68)
ION	(368)
LUNITS	(48)

Entry points: LECDEN

Variables:

R*4	ALP	R*4	ASP	R*4	AZMTH	R*4	FC1
R*4	FC2	R*4	FCE	R*4	FLOW	R*4	FN1
R*4	FN2	R*4	FND	R*4	FNE	R*4	FNVAL
R*4	FSQ	R*4	FUP	R*4	GMT	R*4	H
R*4	HB1	R*4	HB2	R*4	HD	R*4	HLOW
R*4	HLZ	R*4	HMAX	R*4	HT1	R*4	HTE
R*4	HTW	R*4	HUP	R*4	HZ	I*4	I
I*4	ICCP	I*4	IEXD	I*4	IK	I*4	IX
I*4	JDIN	I*4	JH	I*4	JHD	I*4	K
I*4	L	I*4	LANT	I*4	LCON	I*4	LGEO
I*4	LIN	I*4	LIONO	I*4	LMAP	I*4	LNOISE
I*4	LOUT1	I*4	LOUT2	I*4	LOUT3	I*4	LSCRT
I*4	LSEMI	I*4	LTAR	I*4	MAN	I*4	METH
I*4	METHOD	I*4	MONS	R*4	S1	R*4	S2
R*4	SSN	R*4	X1	R*4	XLOW	R*4	XUP
R*4	Y1	R*4	YS	R*4	Z		

Arrays:

R*4	AFAC	(240, 10)
R*4	ALOOK	(6)
R*4	FI	(10, 3)
R*4	FNSQ	(200, 10)
R*4	FOB	(108000)
R*4	HB	(10)
R*4	HI	(10, 3)
R*4	HPRAS	(240, 10)

Subroutines and Functions Referenced:

R*4	MTH$EXP	R*4	MTH$SQRT

Module: lintrp

```
CALL: real function lintrp(freq,RXBW)

 Call Arguments:
   FREQ      current operating frequency
   RXBW      vector of beamwidths for 2 to 40 MHz, every 2 MHz

  **  return value

 Purpose:    interpolates in a vector of frequency dependent beamwidths to return
             beamwidth associated with current frequency

 Included Commons:
  no user defined commons

 Entry points: LINTRP

 Variables:
  R*4     BEAMW         R*4     DELTA         R*4     DELVAL        R*4     FFREQ
  R*4     FREQ          R*4     FREQ1         R*4     FREQINC       I*4     INDX

 Arrays:
@ R*4   RXBW             (20)
```

Module: MAGFIN

CALL: SUBROUTINE MAGFIN (POS,UNE)

Call Arguments:

POS	3 dimensional position array (lat,lon,alt), radians, meters
UNE	3 dimensional geomagnetic field

** return value

Purpose: Calculates the three magnetic field vectors.

Included Commons:
no user defined commons

Entry points: MAGFIN

Variables:

R*4	AR	R*4	BN	R*4	BPHI	R*4	BV
R*4	C	R*4	FM	R*4	FN	R*4	HC
I*4	M	I*4	N	R*4	P1	R*4	P2
R*4	PHI	R*4	RD	R*4	S	R*4	SUMP
R*4	SUMR	R*4	SUMT	R*4	TS		

Arrays:

	R*4	AOR	(7)
	R*4	CP	(7)
	R*4	CT	(7, 7)
	R*4	DP	(7, 7)
	R*4	G	(7, 7)
	R*4	H	(7, 7)
	R*4	P	(7, 7)
@	R*4	POS	(3)
	R*4	SP	(7)
@	R*4	UNE	(3)

Subroutines and Functions Referenced:

R*4	MTH$COS	R*4	MTH$SIN	R*4	MTH$SQRT

Module: MAGVAR

CALL: SUBROUTINE MAGVAR (CENLAT,CENLG,II,CLG)

CAll Arguments:

CENLAT	geographic latitude of point of interest, radians
CENLG	geographic west longitude of point of interest, radians
II	sample area selector
CLG	geographic east longitude of point of interest, radians

** return value

Purpose: Calculates geomagnetic dip and gyro-frequency.

Included Commons:	Size (4 byte words)
DAT	(192)
GEOG	(388)

Entry points: MAGVAR

Variables:

R*4	AK	R*4	BK	R*4	C180	R*4	C360
R*4	CENLAT	R*4	CENLG	R*4	CK	R*4	CKC
R*4	CLG	R*4	COND	R*4	DK	R*4	EEK
R*4	EK	R*4	EPR	R*4	GLG	R*4	GLT
R*4	GOB	R*4	HHM	I*4	II	R*4	PI2
R*4	RZ	R*4	TMP	R*4	X		

Arrays:

R*4	ABIY	(10)
R*4	AMON	(12)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	GLAT	(10)
R*4	GMDIP	(10)
R*4	GY	(10)
R*4	POS	(3)
R*4	PSC	(4)
R*4	RAT	(10)
R*4	RD	(10)
R*4	SUN	(2, 12)
R*4	UNE	(3)

Subroutines and Functions Referenced:

MAGFIN	R*4 MTH$ATAN	R*4 MTH$COS	R*4 MTH$SQ

Module: MAP

CALL: FUNCTION MAP (RLAT,RLONG)

Call Arguments:
RLAT geographic latitude, degrees
RLONG geographic west longitude, degrees

** return value

Purpose: Digitized map of the land boundries of the world

Included Commons:	Size (4 byte words)
LUNITS	(48)

Entry points: MAP

Variables:

CHAR	FILENAME	I*4	LANT	I*4	LAT	I*4	LCON
I*4	LGEO	I*4	LIONO	I*4	LMAP	I*4	LNOISE
I*4	LONG	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	L*1	READ
R*4	RLAT	R*4	RLONG				

Arrays:
L*1 MAPBYT (-90:90, 0:

Subroutines and Functions Referenced:

FOR$CLOSE	FOR$OPEN	I*4 MTH$JISIGN

Module: MERFI

CALL: SUBROUTINE MERFI (P,Y,IER)

Call Arguments:
  P   Input value in the exclusive range (-1.0,1.0)
  Y   Output value of the inverse error function
  IER   Error parameter (output)
         terminal error
         ier = 129 indicates p lies outside the legal range. Plus or minus machine infinity is given as the result (sign is the sign of the function value of the nearest legal argument).

 ** return value

Purpose: MERFI calculates the inverse error function. MERFI IS A PROPRIETARY IMSL ROUTINE WHICH MUST BE AVAILABLE ON YOUR SYSTEM.

Included Commons:
 no user defined commons

Entry points: MERFI

Variables:

R*4	A	R*4	A1	R*4	A2	R*4	A3
R*4	B	R*4	B0	R*4	B1	R*4	B2
R*4	B3	R*4	C0	R*4	C1	R*4	C2
R*4	C3	R*4	D0	R*4	D1	R*4	D2
R*4	E0	R*4	E1	R*4	E2	R*4	E3
R*4	F	R*4	F0	R*4	F1	R*4	F2
R*4	G0	R*4	G1	R*4	G2	R*4	G3
R*4	H0	R*4	H1	R*4	H2	I*4	IER
R*4	P	R*4	RINFM	R*4	SD	R*4	SIGMA
R*4	SN	R*4	W	R*4	WI	R*4	X
R*4	Y	R*4	Z	R*4	Z2		

Subroutines and Functions Referenced:

R*4	MTH$ALOG	R*4	MTH$SIGN	R*4	MTH$SQRT

Module: NOISY

CALL: SUBROUTINE NOISY (KJ,XLA,CEG,ANOS)

Call Arguments:
KJ integer flag to select variable (via array index)
XLA geographic latitude
CEG geographic east longitude
** ANOS return parameter (noise, etc.)

** return value

Purpose: Calculates 1 MHz atmospheric noise levels from numerical maps

Included Commons:	Size (4 byte words)
A1	(14912)

Entry points: NOISY

Variables:

R*4	ALF	R*4	ANOS	R*4	BET	R*4	C1
R*4	CEG	R*4	CX	I*4	J	I*4	K
I*4	KJ	I*4	LM	I*4	LN	R*4	Q
R*4	R	R*4	S1	R*4	SS	R*4	TX
R*4	XLA						

Arrays:

R*4	ABP	(2, 8)
R*4	DP	(29, 16, 8)
R*4	SX	(15)
R*4	ZZ	(29)

Subroutines and Functions Referenced:
R*4 MTH$COS R*4 MTH$SIN

Module: OPLOT

CALL: SUBROUTINE OPLOT

Purpose: Plots the oblique ionograms for all frequencies and power levels.

Included Commons:	Size (4 byte words)
APLT	(36)
INP	(72)
ION	(436)
LUNITS	(48)
RADR	(12)
XXXX	(46900)
RAD2AVA	(40)
TIME	(23)

Entry points: OPLOT

Variables:

R*4	AZMTH	R*4	BANDW	R*4	BMONS	R*4	BWIDTH
CHAR	DATETIME	R*4	ECLUT	R*4	FCLUT	R*4	FREQ
R*4	GMT	I*4	I	I*4	IAZMTH	I*4	IBCL
I*4	IEND	I*4	IEXD	I*4	IF	I*4	IFX
I*4	IGND	I*4	INOISE	CHAR	IPLUS	I*4	IR
I*4	IRANGE	CHAR	IRL	CHAR	IRS	CHAR	IRTICK
I*4	ISNR	I*4	ISSN	I*4	ISTEP	I*4	IT
I*4	ITD	I*4	ITIME	CHAR	ITL	CHAR	ITS
I*4	IX	I*4	IXX	I*4	J	I*4	JDIM
I*4	JFB	I*4	JFE	I*4	JL	I*4	K
I*4	K3	I*4	KFAC	I*4	KMAX	CHAR	LABEL
I*4	LANT	I*4	LCON	I*4	LGEO	I*4	LIONO
I*4	LMAP	I*4	LNOISE	I*4	LOUT1	I*4	LOUT2
I*4	LOUT3	I*4	LSCAN	I*4	LSCRT	I*4	LSEMI
I*4	LTAR	I*4	MAN	I*4	METH	I*4	METHOD
I*4	MONS	CHAR	NGR	CHAR	NGT	I*4	NLAT
I*4	NLON	I*4	NRSCANS	CHAR	NSR	CHAR	NST
R*4	PWID	R*4	PWP	R*4	PWR	R*4	RANGE
R*4	RXNF	R*4	SCVLM	R*4	SSN	R*4	TD
R*4	TLAT	R*4	TLON	R*4	TXLAT	R*4	TXLON
R*4	WT	R*4	X2	R*4	Y2		

Arrays:

R*4	AFREQ	(35)
R*4	ALOOK	(6)
R*4	ANOISE	(35)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)
R*4	FREL	(15)
R*4	HE	(10)
R*4	HF1	(10)
R*4	HF2	(10)
CHAR	IOLINE	(35)
I*4	IOSNR	(333, 35)
CHAR	LABEL1	(2)
I*4	NNLAT	(2)
I*4	NNLON	(2)
R*4	YME	(10)
R*4	YMF1	(10)
R*4	YMF2	(10)

OPLOT (cont.)

Subroutines and Functions Referenced:

R*4 MTH$AMOD	REA992	READ99

Module: PEIR

CALL: FUNCTION PEIR(PHI,TMC,UTC,CHI,SOL,XKP,UT)

Call Arguments:

PHI	corrected geomagnetic latitude in degrees
TMC	corrected geomagnetic time in hours
UTC	local time in hours
CHI	solar zenith distance in degrees
SOL	solar longitude in radians, measured from vernal equinox
XKP	planetary kp index (input as 'kp')
UT	coordinated universal time

** return value

Purpose: Determines the probability of E-layer clutter (and F-layer clutter with an entry point to PFIR).

Included Commons:	Size (4 byte words)
PFE	(24)
RAD2AVA	(40)

Entry points: PEIR, PFIR

Variables:

R*4	A	R*4	B	R*4	BANDW	R*4	CHI
R*4	CLUT	R*4	D1	R*4	D2	R*4	D2R
R*4	E1	R*4	E2	R*4	E3	R*4	ECLUT
R*4	FCLUT	R*4	FLAT	R*4	GY	R*4	H2R
I*4	IBCL	I*4	KFAC	I*4	LSCAN	I*4	NRSCANS
R*4	P1	R*4	P2	R*4	P3	R*4	P4
R*4	P5	R*4	P6	R*4	PHO	R*4	PHI
R*4	PI	R*4	PMC	R*4	R2D	R*4	RXNF
R*4	S	R*4	SCVLM	R*4	SLN	R*4	SOL
R*4	SS	R*4	TMC	R*4	TX	R*4	TY
R*4	UT	R*4	UTC	R*4	WT	R*4	XKP

Subroutines and Functions Referenced:

R*4	MTH$ALOG10	R*4	MTH$ASIN	R*4	MTH$COS	R*4	MTH$EX

Module: pincly

CALL: real function pincly(pos1, pos2, pos3, toa, brt)

Call Arguments:

POS1	latitude, radians.
POS2	west longitude, radians.
POS3	altitude, meters.
TOA	Take-off angle, radians.
BRT	bearing, radians.

** return values

Purpose: Determines overall magnetic field by summation

Included Commons:	Size (4 byte words)
PIR	(12)
RAD2AVA	(48)

Entry points: PINCLY

Variables:

R*4	ALPHA	R*4	BANDW	R*4	BETA	R*4	BRT
R*4	D15	R*4	D2R	R*4	DEG	R*4	DIP
R*4	ECLUT	R*4	EPSLON	R*4	FCLUT	R*4	FIELD_MAG
R*4	FLD_PRODUC	R*4	HORIZ_MAG	I*4	IBCL	I*4	KFAC
I*4	KL	I*4	LSCAN	I*4	NRSCANS	R*4	ORTAP
R*4	ORTMAG	R*4	PI	R*4	PI2	R*4	PINC3

Arrays:

R*4	POS	(3)
R*4	RAY	(3)
R*4	UNE	(3)

Subroutines and Functions Referenced:

	MAGFIN	R*4	MTH$ACOS	R*4	MTH$ACOSD	R*4	MTH$AS
R*4	MTH$SIN	R*4	MTH$SIND	R*4	MTH$SQRT		

Module: POLARC

CALL: SUBROUTINE POLARC (II)

Call Arguments:
II   Sample area indicator

** return value

Purpose: Determines the polar corrections for auroral oval and trough calculations when requested in the input file

Included Commons:	Size (4 byte words)
All	(264)
DAT	(192)
GEOG	(388)
INP	(92)
OVAL	(8)
WABE	(96)

Entry points: POLARC

Variables:

R*4	ALAT	R*4	ALONG	R*4	AZMTH	R*4	CGLAT
R*4	CGLONG	R*4	CKC	R*4	COND	R*4	CONS
R*4	CSDY2	R*4	CZ	R*4	DEG	R*4	DT
R*4	DX1	R*4	DY1	R*4	EARTHR	R*4	EPR
R*4	GHRMT	R*4	GMLAT	R*4	GMLON	R*4	GMT
R*4	GOUT	R*4	HANG	I*4	IEXD	I*4	IGND
I*4	II	I*4	ISNR	I*4	JDAY	I*4	KUT
I*4	MAN	I*4	MDAY	I*4	METH	I*4	METHOD
I*4	MON	I*4	MONS	I*4	MYR	I*4	NGP
R*4	OTH	R*4	PHIA	R*4	PHIAM	R*4	PHIAN
R*4	PI	R*4	PID2	R*4	PIT2	R*4	PKAVG
R*4	RAD	R*4	SSN	R*4	T1	R*4	TAR
R*4	TCT	R*4	TIMEIT	R*4	TPM	R*4	TT
R*4	X1	R*4	XG	R*4	XKP	R*4	XN

Arrays:

R*4	ABIY	(10)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	CD	(24)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	DUM	(4)
R*4	DUMM	(24)

Subroutines and Functions Referenced:

R*4	CGMTIM	R*4	MTH$COS	R*4	MTH$EXP

Module: PRESET

CALL: SUBROUTINE PRESET

Purpose: - Sets predefined program control variables

Included Commons:	Size (4 byte words)
APLT	(60)
APRAM	(4)
DAT	(192)
GEOG	(336)
HOP	(4)
INP	(92)
ION	(436)
IONINP	(480)
LUNITS	(48)
OVAL	(8)
RADR	(24)
RAD2AVA	(40)

Entry points: PRESET

Variables:

R*4	AZMTH	R*4	BANDW	R*4	BWIDTH	R*4	D2R
R*4	DELINC	R*4	EARTHR	R*4	ECLUT	R*4	FCLUT
R*4	FNOISE	R*4	FREQ	R*4	GMLAT	R*4	GMLON
R*4	GLAT	R*4	HANG	I*4	I	I*4	IANT
I*4	IAZMTH	I*4	IBCL	I*4	IEXD	I*4	IFR
I*4	IFX	I*4	IGND	I*4	IMONS	I*4	IPWUS
I*4	IQRT	I*4	ISNR	I*4	ISSN	I*4	IT
I*4	JDIM	I*4	JL	I*4	K3	I*4	KFAC
I*4	KMAX	I*4	LANT	I*4	LCON	I*4	LGEO
I*4	LIMHOP	I*4	LIONO	I*4	LMAP	I*4	LNOISE
I*4	LOUT1	I*4	LOUT2	I*4	LOUT3	I*4	LSCAN
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	MAN
I*4	METH	I*4	METHOD	I*4	MONS	I*4	MYR
I*4	NRSCANS	R*4	OTH	R*4	PI	R*4	PID2
R*4	PIT2	R*4	PKAVG	R*4	PWID	R*4	PWP
R*4	PWR	R*4	PWUS	R*4	R2D	R*4	RXNF
R*4	SCVLM	R*4	SIZE	R*4	SNOISE	R*4	SSN
R*4	TAR	R*4	TIMEIT	R*4	TLTFAC	R*4	VSTEER
R*4	WT	R*4	X1	R*4	X2	R*4	XKP
R*4	Y1	R*4	Y2				

Arrays:

R*4	ABIY	(10)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	DUM	(4)
R*4	DUMM	(24)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)
R*4	FESINP	(30)
R*4	FFAK	(2)
R*4	FIINP	(30)
R*4	FREL	(15)
R*4	GLAT	(10)

```
R*4   GY              (10)
R*4   HE              (10)
R*4   HF1             (10)
R*4   HF2             (10)
R*4   HIINP           (30)
R*4   PSC             (4)
R*4   RAT             (10)
R*4   RD              (10)
R*4   YIINP           (30)
R*4   YME             (10)
R*4   YMF1            (10)
R*4   YMF2            (10)
```

Subroutines and Functions Referenced:

```
R*4   MTH$ALOG10
```

Module: RADAR

CALL: SUBROUTINE RADAR (IESFLG,lomuf)

Call Arguments:

IESFLG	use(+)/don't use(-) E_s
LOMUF	integer flag to indicate propagation over-the-MUF has occurred

** return value

Purpose: Takes the oblique information from BAKSCT and evaluates the system parameters and losses, and calculates sporadic-E modes and losses. Backscatter control routine. Searches the oblique frequency tables for the reflectrix with constant frequency. If over the MUF these losses are calculated. Then the backscatter returns are computed.

Included Commons:	Size (4 byte words)
APLT	(60)
APRAM	(4)
A2	(432000)
DAT	(192)
FOLO	(5040)
HGH	(28800)
HOP	(4)
INP	(92)
ION	(368)
MIMSY	(2520)
PLT	(3640)
RADR	(16)
CPTEST	(120)

Entry points: RADAR

Variables:

R*4	AK	R*4	AZMTH	R*4	BK	R*4	BWIDTH
R*4	C180	R*4	C360	R*4	CK	R*4	DELINC
R*4	DK	R*4	EEK	R*4	EK	R*4	FNOISE
R*4	FREQ	R*4	GLG	R*4	GMT	R*4	GT
R*4	HANG	I*4	I	I*4	IANT	I*4	IAZMTH
I*4	IDX_F2_CRI	I*4	IDX_NOW_CR	I*4	IESFLG	I*4	IEXD
I*4	IFR	I*4	IGND	I*4	IMONS	I*4	IPWUS
I*4	IQRT	I*4	ISNR	I*4	ISSN	I*4	IT
I*4	J	I*4	JDIN	I*4	JEND	I*4	JFV
I*4	JK	I*4	JX	I*4	K	I*4	KMAX
I*4	KND	I*4	LIMHOP	I*4	LOMUF	I*4	M
I*4	MAN	I*4	METH	I*4	METHOD	I*4	MONS
R*4	MSLOP	I*4	NBLANK	R*4	OTH	R*4	PITW
R*4	PKAVG	R*4	PWID	R*4	PWR	R*4	RCSDEL
R*4	RZ	R*4	SECPHE	R*4	SIPHE	R*4	SNOISE
R*4	SSN	R*4	TAR	R*4	TIMEIT	R*4	VSTEER
R*4	X1	R*4	X2	R*4	Y1	R*4	Y2
R*4	ZWR						

Arrays:

R*4	AFAC	(240, 10)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	DELH	(10, 45)
R*4	DELI	(10, 45)
R*4	FI	(10, 3)

RADAR (cont.)

```
R*4   FOB         (240, 45, 1
R*4   HI          (10, 3)
R*4   HPRIM       (240, 10)
R*4   HTRUE       (240, 10)
I*4   IDIST       (8, 45)
I*4   IDLAY       (8, 45)
I*4   ILAY10      (45, 10)
I*4   ILAYER      (45, 4)
I*4   JNUM        (10)
I*4   JNUMM       (3, 10)
I*4   JS          (4, 45)
I*4   LAYTYP      (4)
R*4   SUN         (2, 12)
R*4   YI          (10, 3)
```

Subroutines and Functions Referenced:

```
      ANT00          ANT01          ANT02          ANT03

      ANT06          ANT07          ANT08          ANT09

      ANT12          ANT13          ANT14          CUSPIN
R*4   MTH$SQRT       SELION         SETION         SETPLT
```

Module: RADARC

CALL: PROGRAM RADARC

Purpose: Main program which controls all functions, sets date and time, and sets an error function to avoid unwanted warnings during runtime.

Included Commons: byte words)

A1	4912)
A2	32000)
A3	(23712)
A11	(264)
ALLAMP	(10656)
ANT	(372)
APLT	(60)
APRAM	(4)
CPTEST	(3000)
CPTRP	(28)
CUSP	(640)
DAT	(192)
DUD	(1248)
ES	(160)
ESTAB	(3996)
FOLO	(7920)
FONE	(480)
FRQCHK	(8)
GEOG	(388)
HGH	(28800)
ILOS	(2880)
INP	(92)
ION	(436)
LUNITS	(48)
OVAL	(8)
PLT	(5080)
PLTAB	(11992)
RADR	(24)
SLS	(88)
TIME	(23)
TTSIZE	(180)
WMAPS	(1824)
XXXX	(46900)

Entry points: RADARC

Variables:

R*4	ASKP	R*4	AZMTH	R*4	BWID	R*4	BWIDTH
R*4	CKC	R*4	COND	CHAR	DATETIME	R*4	DEG
R*4	DELINC	R*4	EARTHR	R*4	EPR	R*4	FNOISE
R*4	FREQ	R*4	GAZM	R*4	GMLAT	R*4	GMLON
R*4	GMT	R*4	HANG	I*4	IANT	I*4	IAZMTH
I*4	ICFR	I*4	ICNR	I*4	ICP	I*4	IDUMM
I*4	IERRNO	I*4	IEXD	I*4	IFR	I*4	IFX
I*4	IGND	I*4	IMONS	I*4	IPWUS	I*4	IQRT
I*4	ISNR	I*4	ISSN	I*4	IT	I*4	JDIM
I*4	JFR	I*4	JL	I*4	JNR	I*4	K3
I*4	KMAX	I*4	L	I*4	LAMT	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	MAN
I*2	MAXERR	I*4	MAXFRQ	I*4	MCP	I*4	METH
I*4	METHOD	I*4	MONS	I*4	MYR	L*4	OCONTN

L*4	OCOUNT	L*4	OLOG	R*4	OTH	L*4	OTYPE
R*4	PI	R*4	PID2	R*4	PIT2	R*4	PKAVG
R*4	PREFRQ	R*4	PWID	R*4	PWP	R*4	PWR
R*4	RAD	R*4	SIGBAK	R*4	SKPSIG	R*4	SNOISE
R*4	SSN	R*4	TAR	R*4	TIMEIT	R*4	VSTEER
R*4	X1	R*4	X2	R*4	XKP	R*4	Y1
R*4	Y2						

Arrays:

R*4	AB	(76, 6)
R*4	ABIY	(10)
R*4	ABP	(2, 8)
R*4	ACHI	(2, 12)
R*4	ADV	(4, 45)
R*4	AFAC	(240, 10)
R*4	AFREQ	(35)
R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	AMPCP	(4, 4)

Subroutines and Functions Referenced:

DATIME	ERRSET	IONGEN	R*8 MTH$DA

Module: REA992

CALL: SUBROUTINE REA992

Purpose: Reads FOR099.dat scratch file and generates the ALLMODES.DAT output.

Included Commons:	Size (4 byte words)
LUNITS	(48)
TIME	(23)

Entry points: REA992

Variables:

R*4	ANGMIN	R*4	AZMTH	R*4	BINVAL	R*4	BINVALC
R*4	BMONS	CHAR	DATETIME	I*4	ENV1	I*4	ENV2
I*4	I	I*4	IBIN	I*4	IBINS	I*4	IDATAIN
I*4	IREC	I*4	ISSN	I*4	IT	I*4	ITEM
I*4	J	I*4	JBEG	I*4	JBIN	I*4	JEND
I*4	JFLAGG	I*4	JOUT	I*4	KBIN	I*4	KBINC
I*4	KREC	I*4	L	I*4	LAMT	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LREC	I*4	LSCRT	I*4	LSEMI	I*4	LTAR
I*4	NLAT	I*4	NLON	R*4	OTH	R*4	PKAVG
R*4	PWID	R*4	PWR	R*4	TARSIZ	R*4	TIMEIT
R*4	TIMLOG	R*4	TXLAT	R*4	TXLON	R*4	WSIZE
R*4	WSTART	R*4	WSTEP				

Arrays:

R*4	DATA	(5000, 19)
R*4	DATAIN	(19)
R*4	ENVELP	(201, 19)
R*4	FREQ	(5000)
I*4	IDATA	(5000)
I*4	IENVLP	(201)
I*4	INDEX	(5000)
R*4	RANGE	(5000)
R*4	SNR	(5000)

Subroutines and Functions Referenced:

FOR$CLOSE FOR$OPEN

Module: READ99

CALL: SUBROUTINE READ99

Purpose: Reads the FOR099.dat scratch file and generates the fortran unit 10 combined raysets table.

Included Commons:	Size (4 byte words)
LUNITS	(48)
TIME	(23)

Entry points: READ99

Variables:

R*4	ANGMIN	R*4	AZMTH	R*4	BMONS	CHAR	DATETIME
I*4	I	I*4	IHITE	I*4	IMAX	I*4	IMIN
I*4	INDEXX	I*4	IOUT	I*4	IREC	I*4	IRNGE
I*4	ISAMP	I*4	ISAVE	I*4	ISSN	I*4	IT
I*4	ITEM	I*4	J	I*4	JBEG	I*4	JEND
I*4	JEND2	I*4	JFLAGG	I*4	JMIN	I*4	JOUT
I*4	KREC	I*4	L	I*4	LANT	I*4	LCON
I*4	LGEO	I*4	LIONO	I*4	LMAP	I*4	LNOISE
I*4	LOUT1	I*4	LOUT2	I*4	LOUT3	I*4	LREC
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	MINFLG
I*4	NLAT	I*4	NLON	R*4	OTH	R*4	PKAVG
R*4	PWID	R*4	PWR	R*4	RMAX	R*4	RMIN
R*4	SNRMAX	R*4	TARSIZ	R*4	TIMEIT	R*4	TIMLOG
R*4	TXLAT	R*4	TXLON	R*4	WMAX	R*4	WMIN
R*4	WSIZE	R*4	WSTART	R*4	WSTEP		

Arrays:

R*4	DATA	(5000, 19)
R*4	DATA2	(5000, 19)
R*4	DATAIN	(19)
R*4	FREQ	(5000)
I*4	IDATA	(5000, 2)
I*4	IDATA2	(5000, 2)
I*4	IDATAIN	(2)
I*4	INDEX	(5000)
I*4	NHOP1	(5000)
I*4	NHOP2	(5000)
R*4	RANGE	(5000)
R*4	SNR	(5000)

Subroutines and Functions Referenced:

FOR$CLOSE SORT

Module: READIN

CALL: SUBROUTINE READIN(ITSTR, ITSTP, ITSKP)

Call Arguments

ITSTR	start time for time loop, UT
ITSTP	stop time for time loop, UT
ITSKP	skip time for time loop, UT

** return value

Purpose: Reads the program control (input) variables from user input file XXXXX.INP

Included Commons:	Size (4 byte words)
APLT	(60)
GEOG	(336)
HOP	(4)
INP	(92)
ION	(436)
IONINP	(480)
LUNITS	(48)
OVAL	(8)
RADR	(24)
RAD2AVA	(48)

Entry points: READIN

Variables:

R*4	AZCOUNT	R*4	AZMTH	R*4	BANDW	CHAR	BLANK
R*4	BWIDTH	R*4	DELINC	R*4	ECLUT	R*4	FCLUT
R*4	FLUX	R*4	FNOISE	R*4	FREQ	R*4	GMT
R*4	HANG	I*4	IANT	I*4	IAZMTH	I*4	IBCL
I*4	IEXD	I*4	IFLAG	I*4	IFR	I*4	IFX
I*4	IGND	I*4	II	I*4	IMONS	I*4	INDEX
I*4	IOSTAT	I*4	IPWUS	I*4	IQRT	I*4	ISNR
I*4	ISSN	I*4	IT	I*4	ITSKP	I*4	ITSTP
I*4	ITSTR	I*4	J	I*4	JDIM	I*4	JL
I*4	K	I*4	K3	I*4	K3I	R*4	KFAC
I*4	KMAX	I*4	LANT	I*4	LCON	I*4	LGEO
I*4	LIMHOP	I*4	LIONO	I*4	LMAP	I*4	LNOISE
I*4	LOUT1	I*4	LOUT2	I*4	LOUT3	I*4	LSCAN
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	M
I*4	MAN	I*4	METH	I*4	METHOD	CHAR	MODIFIER
I*4	MONS	I*4	MYR	I*4	NRSCANS	R*4	ORTAP
R*4	ORTMAG	R*4	OTH	R*4	PKAVG	R*4	PWID
R*4	PWP	R*4	PWR	R*4	PWUS	CHAR	RECORD
R*4	RXNF	R*4	SCVLM	R*4	SNOISE	R*4	SSN
CHAR	TAB	R*4	TAR	R*4	TIMEIT	R*4	VALUE
CHAR	VARNAME	R*4	WT	R*4	X1	R*4	X2
R*4	XKP	R*4	Y1	R*4	Y2		

Arrays:

R*4	ABIY	(10)
R*4	ALOOK	(6)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)

READIN (cont.)

```
R*4   FESINP          (10, 3)
R*4   FFAK            (2)
R*4   FIINP           (10, 3)
R*4   FREL            (15)
R*4   GLAT            (10)
R*4   GY              (10)
R*4   HE              (10)
R*4   HF1             (10)
R*4   HF2             (10)
R*4   HIINP           (10, 3)
R*4   PSC             (4)
R*4   RAT             (10)
R*4   RD              (10)
CHAR  WORD            (12)
R*4   YIINP           (10, 3)
R*4   YME             (10)
R*4   YMF1            (10)
```

Subroutines and Functions Referenced:

```
      CASE                 FOR$CLOSE          FOR$OPEN        R*4  MTH$AL
```

Module: REDMAP

Call Arguments:
  LOCK
  NEWNOISE flag to indicate use(+)/don't use(-) most recent CCIR noise

 ** return value

CALL: SUBROUTINE REDMAP (LOCK,NEWNOISE)

Purpose: Reads ionospheric data files for the:
  a. sporadic E-layer
  b. F2-layer
  c. E-layer
  d. CCIR atmospheric noise files

Included Commons:	Size (4 byte words)
A1	(14912)
A2	(31008)
A3	(23712)
A11	(264)
DUD	(1248)
INP	(68)
LUNITS	(48)

Entry points: REDMAP

Variables:

R*4	AZMTH	CHAR	DFILE	R*4	GMT	I*4	I
I*4	ICCP	I*4	IEXD	CHAR	IFILE	I*4	IMON
I*4	J	I*4	K	I*4	L	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOCK	I*4	LOUT1	I*4	LOUT2
I*4	LOUT3	I*4	LSCRT	I*4	LSEMI	I*4	LTAR
I*4	MAN	I*4	METH	I*4	METHOD	I*4	MONS
I*4	NEWNOISE	R*4	SSN	R*4	X1	R*4	Y1

Arrays:

R*4	ABP	(2, 8)
R*4	ABPI	(2, 2)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	D	(13, 76, 6)
R*4	DABP	(2, 6)
R*4	DMON	(12)

Subroutines and Functions Referenced:
  FOR$CLOSE   FOR$OPEN

Module: SELDST

CALL: SUBROUTINE SELDST(DEL,HP, GDR,DELAY)

Call Arguments:

DEL	Take-off angle, degrees.
HP	virtual height, km
GDR	great circle distance, km
DELAY	slant time delay, ms

** return value

Purpose: This routine calculates path geometry for given ionospheric properties.

Included Commons:	Size (4 byte words)
DAT	(192)

Entry points: SELDST

Variables:

R*4	AK	R*4	BK	R*4	C180	R*4	C360
R*4	CK	R*4	DEL	R*4	DELAY	R*4	DK
R*4	EEK	R*4	EK	R*4	GDR	R*4	GLG
R*4	GT	R*4	HP	R*4	PHE	R*4	PITW
R*4	RAY	R*4	RCSDEL	R*4	RZ	R*4	SIPHE

Arrays:

R*4	AMON	(12)
R*4	SUN	(2, 12)

Module: SELION

CALL: SUBROUTINE SELION

Purpose: Selects the closest control area to the ionospheric return. The ionospheric description at this control point is selected to represent the spherically symmetric model used over the hop, which permits quick closed-form ray path calculations.

Included Commons:	Size (4 byte words)
APLT	(60)
CPTEST	(3000)
DAT	(192)
FOLO	(7920)
GEOG	(388)
HGH	(28800)
HOP	(4)
ION	(368)
MIMSY	(2520)
PLT	(3640)
RADR	(16)

Entry points: SELION

Variables:

R*4	ADEL	R*4	AK	R*4	BK	R*4	BMONS
R*4	C180	R*4	C360	R*4	CK	R*4	CKC
R*4	COND	R*4	DEL	R*4	DELAY	R*4	DELINC
R*4	DINC	R*4	DK	R*4	DWR	R*4	EEK
R*4	EK	R*4	EPR	R*4	FC	R*4	FNOISE
R*4	FREQ	R*4	FV	R*4	GDR	R*4	GLG
R*4	GT	R*4	HP	R*4	HT	R*4	HWIDTH
I*4	I	I*4	IANT	I*4	IAZMTH	I*4	IFR
I*4	IFV	I*4	IPWUS	I*4	IQRT	I*4	ISSN
I*4	IT	I*4	J	I*4	J1	I*4	J2
I*4	JDIN	I*4	JJ	I*4	JO	I*4	K3
I*4	KMAX	I*4	LIMHOP	R*4	PITW	R*4	PWID
R*4	PWR	R*4	RNGDIF	R*4	RZ	R*4	SNOISE
R*4	SOFAR	R*4	SPH	R*4	X2	R*4	XFSQ
R*4	XHPTR	R*4	XMUT	R*4	Y2		

Arrays:

R*4	ABIY	(10)
R*4	AFAC	(240, 10)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	CNR	(8, 45)
R*4	DELH	(10, 45)
R*4	DELI	(10, 45)
R*4	FI	(10, 3)
R*4	GDIST	(4, 45)
R*4	GLAT	(10)
R*4	GMDIP	(10)
R*4	GY	(10)
R*4	HI	(10, 3)
R*4	HPP	(4, 45)
R*4	HPRIM	(240, 10)
R*4	HTRUE	(240, 10)

SELION (cont.)

```
  I*4  IDIST          (8, 45)
  I*4  IDLAY          (8, 45)
  I*4  ILAY1          (45)
  I*4  ILAY10         (45, 10)
  I*4  ILAY2          (45)
  I*4  ILAY3          (45)
  I*4  ILAY4          (45)
  I*4  JNUM           (10)
  I*4  JNUMM          (3, 10)
  I*4  JS             (4, 45)
  R*4  PSC            (4)
  R*4  RAT            (10)
  R*4  RD             (10)
  R*4  SDELAY         (4, 45)
  R*4  SNR            (8, 45)
  R*4  SUN            (2, 12)
  R*4  TLOSS          (4, 45)
  R*4  YI             (10, 3)
```

Subroutines and Functions Referenced:
SELDST

Module: SETCP

CALL: SUBROUTINE SETCP

Purpose: Determines auroral losses for cusp region from table look-up. Finds signal-to-noise values for cusp region.

Included Commons:	Size (4 byte words)
ANT	(372)
APLT	(56)
CPTRP	(28)
CUSP	(1600)
DAT	(192)
INP	(72)
LUNITS	(48)
MIMSY	(2520)
RADR	(24)

Entry points: SETCP

Variables:

R*4	ADEL	R*4	AK	R*4	AZMTH	R*4	BK
R*4	BWIDTH	R*4	C180	R*4	C360	R*4	CK
R*4	DEL	R*4	DELI	R*4	DELINC	R*4	DK
R*4	EEK	R*4	EK	R*4	FNOISE	R*4	FREQ
R*4	GAIN	R*4	GAZM	R*4	GLG	R*4	GLT
R*4	GMT	R*4	HWIDTH	I*4	I	I*4	IANT
I*4	ICFR	I*4	ICNR	I*4	ICP	I*4	IDEL
I*4	IEXD	I*4	IFR	I*4	IGAIN	I*4	IGND
I*4	IPWUS	I*4	ISNR	I*4	J	I*4	JFR
I*4	JNR	I*4	KMAX	I*4	LANT	I*4	LCON
I*4	LGEO	I*4	LHOP	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	MAN
I*4	MCP	I*4	METH	I*4	METHOD	I*4	MONS
R*4	PI2	R*4	PWID	R*4	PWP	R*4	PWR
R*4	RZ	R*4	SIGBAK	R*4	SNOISE	R*4	SSN
R*4	X1	R*4	X2	R*4	Y1	R*4	Y2

Arrays:

R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMPCP	(4, 10)

Module: SETION

CALL: SUBROUTINE SETION

Purpose: Determines the system losses. It calls SIGNT, a routine that permits a desired sea or land backscatter cross-section to be used. Adjustments have been made to this routine to determine losses over the MUF.

Included Commons:	Size (4 byte words)
ANT	(368)
APLT	(56)
DAT	(192)
ES	(120)
FOLO	(5040)
GEOG	(280)
HGH	(28800)
HOP	(4)
ILOS	(2880)
INP	(68)
ION	(436)
LUNITS	(48)
MIMSY	(2520)
PLT	(5080)
RADR	(24)

Entry points: SETION

Variables:

R*4	ADL	R*4	AK	R*4	AREF	R*4	AZMTH
R*4	BK	R*4	BWIDTH	R*4	C180	R*4	C360
R*4	CK	R*4	COSP	R*4	DEL	R*4	DELINC
R*4	DK	R*4	EEK	R*4	EK	R*4	ESD
R*4	FC	R*4	FNOISE	R*4	FREQ	R*4	FV
R*4	FVI	R*4	GLG	R*4	GLT	R*4	GMT
R*4	HT	R*4	HWIDTH	I*4	I	I*4	IANT
I*4	IAZMTH	I*4	ICCP	I*4	IEXD	I*4	IFR

Arrays:

R*4	ABIY	(10)
R*4	AC	(10)
R*4	ADV	(4, 45)
R*4	AFAC	(240, 10)
R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	ANDV	(4, 45)
R*4	AOF	(4, 45)
R*4	ARF	(4, 45)
R*4	BC	(10)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	DELH	(10, 45)
R*4	DELI	(10, 45)
R*4	FFAK	(2)
R*4	FI	(10, 3)
R*4	FOES	(10, 3)
R*4	FREL	(15)
R*4	GLAT	(10)

```
R*4   GRLOS     (45)
R*4   GY        (10)
R*4   HE        (10)
R*4   HF1       (10)
R*4   HF2       (10)
R*4   HPRIM     (240, 10)
R*4   HTRUE     (240, 10)
I*4   IAMP      (8, 45)
I*4   IDIST     (8, 45)
I*4   IDLAY     (8, 45)
I*4   ILAY10    (45, 10)
I*4   ILAYER    (180)
I*4   JNUM      (10)
I*4   JS        (4, 45)
R*4   RD        (10)
R*4   SUN       (2, 12)

Subroutines and Functions Referenced:
      ESDIS          R*4  GAUSS          R*4  MTH$ALOG          R*4  MTH$CO
```

Module: SETPLT

CALL: SUBROUTINE SETPLT (INT)

Call arguments:
INT set page of figure being plotted

** return value

Purpose: Plot control routine that sets up variables to be plotted

Included Commons:	Size (4 byte words)
ANT	(180)
APLT	(60)
CINI	(640)
CUSP	(1120)
DAT	(192)
ES	(120)
FOLO	(7920)
GEOG	(388)
HOP	(4)
INP	(72)
ION	(436)
LUNITS	(48)
MIMSY	(2520)
PLT	(5080)
PLTAB	(11992)
RADR	(16)
SLS	(88)

Entry points: SETPLT

Variables:

R*4	ADEL	R*4	AK	R*4	ASKP	R*4	AZMTH
R*4	BK	R*4	BWIDTH	R*4	C180	R*4	C360
R*4	CK	R*4	CKC	R*4	COND	R*4	DADD
R*4	DEL	R*4	DELINC	R*4	DK	R*4	EEK
R*4	EK	R*4	EPR	R*4	FNOISE	R*4	FREQ
R*4	GAIN	R*4	GLG	R*4	GLT	R*4	GMT
I*4	I	I*4	IANT	I*4	IAZMTH	I*4	IDT
I*4	IES	I*4	IEXD	I*4	IFR	I*4	IFX
I*4	IGND	I*4	IMONS	I*4	INT	I*4	IPWUS
I*4	IQRT	I*4	IRAN	I*4	IREFF	I*4	ISNR
I*4	ISNRMX	I*4	ISSN	I*4	IT	I*4	IZER
I*4	J	I*4	JDIM	I*4	JJ	I*4	JL
I*4	K3	I*4	KCP	I*4	KMAX	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIMHOP	I*4	LIONO
I*4	LMAP	I*4	LNOISE	I*4	LOUT1	I*4	LOUT2
I*4	LOUT3	I*4	LSCRT	I*4	LSEMI	I*4	LTAR
I*4	MAN	I*4	METH	I*4	METHOD	I*4	MONS
I*4	NDOT	I*4	NS	R*4	PI2	R*4	PWID

Arrays:

R*4	ABIY	(10)
R*4	AGAIN	(45)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	AMP	(8, 45)
R*4	AMPCP	(4, 10)
R*4	CLAT	(10)
R*4	CLCK	(10)

SETPLT (cont.)

R*4	CLONG	(10)
R*4	CNR	(8, 45)
R*4	DELCP	(4, 10)
R*4	DELH	(10, 45)
R*4	DELI	(10, 45)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)
R*4	FOES	(10, 3)
R*4	FREL	(15)
R*4	FVCP	(4, 10)
R*4	GDIST	(4, 10)
R*4	GLAT	(10)
R*4	GMDIP	(10)
R*4	GY	(10)
R*4	HE	(10)
R*4	HF1	(10)
R*4	HF2	(10)
I*4	IAMP	(8, 45)
I*4	IAMPCP	(4, 10)
I*4	IDIST	(8, 45)
I*4	IDLAY	(8, 45)
I*4	IDLYCP	(4, 10)
I*4	IDSTCP	(4, 10)
I*4	IGDLCP	(4, 10)
I*4	ILAY10	(45, 10)
I*4	ILAYER	(180)
I*4	ILY	(4, 10)
I*4	ISCLS	(5, 2)
I*4	ITIM	(5, 2)
I*4	JNUM	(10)
I*4	JS	(4, 45)
I*4	LANG	(333, 3)
I*4	LLAYER	(333, 3)
I*4	LSNR	(333, 3)
R*4	PSC	(4)
R*4	RAT	(10)
R*4	RD	(10)
R*4	SDELAY	(4, 10)
R*4	SNR	(8, 45)

Subroutines and Functions Referenced:

ALLFRQ AMPLOT ESTERP INTERP

Module: SIGNT

CALL: SUBROUTINE SIGNT (SIGNOT)

```
Call Arguments:
  SIGNOT   backscatter coeficient adjustment (currently 10**-2.9)

 ** return value

Purpose:   adjusts the backscatter coefficient

Included Commons:
 no user defined commons

Entry points: SIGNT

Variables:
 R*4    DB            R*4    SIGNOT       R*4    X
```

Module: SLANTY

CALL: SUBROUTINE SLANTY(lomuf)

Call Arguments:
** LOMUF flag to signal over-the-MUF propagation has occurred.

** return value

Purpose: Gathers all informantion on modes,losses, and environmental noise, and puts it in the form of the radar equation. Also gets the spread Doppler clutter by a call to ABILITY. Finds the raysets for the E, F1, and F2 layers. This routine gathers all results and puts them in the form of radar equation.

Included Commons:	Size (4 byte words)
ANT	(368)
APLT	(60)
CPTEST	(3000)
DAT	(192)
FOLO	(9360)
GEOG	(388)
GROUND	(720)
HGH	(28800)
HOP	(4)
ILOS	(2880)
INP	(92)
ION	(368)
PLT	(3640)
RADR	(16)
TIME	(23)
TTSIZE	(180)
AVAIL_INP	(112)
MIMSY	(2520)
RAD2AVA	(40)
PIR	(24)
OVAL	(8)

Entry points: SLANTY

Variables:

R*4	ABPS1	R*4	ABSA1	R*4	ABSB	R*4	ADEL
R*4	ADEV	R*4	ADJ	R*4	ADVO	R*4	AK
R*4	AMPANT	R*4	ANOISE	R*4	AREA	R*4	AZMTH
R*4	AZRAD	R*4	BANDW	R*4	BANDWO	R*4	BK
R*4	BMONS	R*4	BWIDTH	R*4	C180	R*4	C360
R*4	CIT	R*4	CK	R*4	CKC	R*4	CLOCK
R*4	COND	CHAR	DATETIME	R*4	DEL	R*4	DELINC
R*4	DINC	R*4	DK	R*4	DUMMY	R*4	DWR
R*4	ECLUT	R*4	ECLUTO	R*4	EEK	R*4	EK
R*4	EPR	R*4	ETA	R*4	F2C	R*4	FC
R*4	FCLUT	R*4	FCLUTO	R*4	FMUF	R*4	FNOISE
R*4	FREQ	R*4	GAIN	R*4	GCD	R*4	GCDRAD
R*4	GLG	R*4	GMT	R*4	GT	R*4	HANG
R*4	HEIGHT	R*4	HP	R*4	HWIDTH	I*4	I
I*4	I2	I*4	IANT	I*4	IAZMTH	I*4	IBCL
I*4	IDUM	I*4	IEXD	I*4	IFR	I*4	IGND
I*4	IK	I*4	IMUF	I*4	IPWUS	I*4	IQRT
I*4	ISNR	I*4	ISSN	I*4	ISTART	I*4	IT
I*4	IYEAR	I*4	J	I*4	JDIN	I*4	JEND

SLANTY (cont.)

I*4	JHOP	I*4	JUG	R*4	KFAC	R*4	KFACO
I*4	KMAX	I*4	KNT	R*4	LAMLOG	R*4	LAMSQ
I*4	LIMHOP	I*4	LOMUF	I*4	LSCAN	I*4	LSCANO
I*4	MAN	I*4	METH	I*4	METHOD	CHAR	MMODES
I*4	MONS	I*4	MYR	I*4	NFAC	I*4	NFG
I*4	NHOPS	I*4	NRSCANS	I*4	NSC	R*4	OBF
R*4	OMUF	R*4	ORTANG	R*4	OTH	R*4	P
R*4	PHE	R*4	PI	R*4	PINC	R*4	PITW
R*4	PKAVG	R*4	PROBE	R*4	PROBF	R*4	PT
R*4	PVBAR	R*4	PWID	R*4	PWR	R*4	R4TH
R*4	RANGE	R*4	RAY	R*4	RBORE	R*4	RCSDEL
R*4	RGLAT	R*4	RGLON	R*4	RLAT	R*4	RLATRAD
R*4	RLON	R*4	RLONRAD	R*4	RXANTL	R*4	RXNF
R*4	RZ	R*4	SCLOS	R*4	SCVLIM	R*4	SCVLM
R*4	SECPHE	R*4	SIGBAK	R*4	SIGLOG	R*4	SIGMAC
R*4	SIPHE	R*4	SLANT	R*4	SLAT	R*4	SLATRAD
R*4	SLON	R*4	SLONRAD	R*4	SNOISE	R*4	SPLOS
R*4	SSN	R*4	TAR	R*4	TARSIZ	R*4	TCPDB
R*4	TCS	R*4	TIMEIT	R*4	TIMLOG	R*4	TNOISE
R*4	TOA	R*4	TODSTART	R*4	TODSTEP	R*4	TODSTOP
R*4	VC	R*4	WT	R*4	WTO	R*4	X1
R*4	X2	R*4	XKP	R*4	XXKP	R*4	Y1
R*4	Y2	R*4	Z	R*4	ZK		

Arrays:

R*4	ABIY	(10)
R*4	ADV	(4, 45)
R*4	AFAC	(240, 10)
R*4	AGAIN	(45)
R*4	ALOOK	(6)

Subroutines and Functions Referenced:

	ABILITY_V3		CGMCS		CHANY		CORDY
R*4	MTH$ALOG10	R*4	MTH$ASIN	R*4	MTH$COS	R*4	MTH$SQ

Module: SNRPRT

CALL: SUBROUTINE SNRPRT

Purpose: Routine that sets up variables and prints the tabular output

Included Commons:	Size (4 byte words)
ALLAMP	(10656)
APLT	(36)
INP	(88)
LUNITS	(48)
RADR	(12)

Entry points: SNRPRT

Variables:

R*4	AZMTH	R*4	BMONS	R*4	BWIDTH	R*4	FREQ
R*4	FREQQ	R*4	GMT	I*4	I	I*4	IAZMTH
I*4	IEXD	I*4	IGMT	I*4	IGND	I*4	ISNR
I*4	ISSN	I*4	IVAL	I*4	IZZZ	I*4	J
I*4	KMAX	I*4	LANT	I*4	LCON	I*4	LGEO
I*4	LIONO	I*4	LMAP	I*4	LNOISE	I*4	LOUT1
I*4	LOUT2	I*4	LOUT3	I*4	LSCRT	I*4	LSEMI
I*4	LTAR	I*4	MAN	I*4	METH	I*4	METHOD
I*4	MONS	I*4	NC	I*4	NLAT	I*4	NLON
I*4	NS	I*4	NSYM	R*4	OTH	R*4	PKAVG
R*4	PWID	R*4	PWP	R*4	PWR	R*4	RANGE
R*4	SSN	R*4	TAR	R*4	TIMEIT	R*4	TIMLOG
R*4	TXLAT	R*4	TXLON	R*4	X1	R*4	X2
R*4	Y1	R*4	Y2				

Arrays:

R*4	ALOOK	(6)
I*4	LAYSMB	(333, 4)
I*4	LAYSNR	(333, 4)
I*4	NNLAT	(2)
I*4	NNLON	(2)
R*4	SNR	(333)

Subroutines and Functions Referenced:

R*4 MTH$ALOG10

Module: SOLR

CALL: FUNCTION SOLR(NY,ND,UT)

Call Arguments:
NY year including century
ND day of year
UT universal time in hours

** return value

Purpose: Updates orbital elements of of epoch

Included Commons:	Size (4 byte words)
SOL	(56)

Entry points: SOLR

Variables:

R*4	CCG	R*4	COB	R*4	DC	R*4	DE
R*4	DEC	R*4	DES	R*4	DJ	R*4	DL
R*4	DP	R*4	EC	R*4	EO	R*4	EOB
R*4	EQT	R*4	FUT	R*4	GHA	R*4	HTR
I*4	K	I*4	L	I*4	ND	I*4	NY
R*4	PD2	R*4	PHS	R*4	PI	R*4	PI2
R*4	PO	R*4	R2D	R*4	SE2	R*4	SEC
R*4	SL	R*4	SLG	R*4	SMA	R*4	SML
R*4	SOB	R*4	SOL	R*4	SPG	R*4	SRA
R*4	SSG	R*4	THS	R*4	UT	R*4	UTR
R*4	YX						

Subroutines and Functions Referenced:

R*4	FKEP	R*4	MTH$ASIN	R*4	MTH$ATAN2	R*4	MTH$CO

Module: SORT

CALL: SUBROUTINE SORT (ARRAY,INDEX,NPTS)

Call Arguments:
```
  ARRAY       data array to be sorted, dimensioned array(npts)
 ** INDEX     index generated for array, dimensioned index(npts)
  NPTS      dimension of array, index

 ** return value
```

Purpose: Sorts ARRAY, returning an index to sorted values

Included Commons:
no user defined commons

Entry points: SORT

Variables:

I*4	I	I*4	ITEMP	I*4	J	I*4	K
I*4	L	I*4	N	I*4	NPTS		

Arrays:
```
@ R*4  ARRAY      (*)
@ I*4  INDEX      (*)
```

Module: SYSSY

CALL: SUBROUTINE SYSSY (G,I,P,NN,FM)

Call Arguments:

G	geomagnetic latitude, radians	
I	month	
P	local mean time at sample area	
NN	not used	
**	FM	auroral loss, dB

** return value

Purpose: Determines auroral loss from tables

Included Commons:	Size (4 byte words)
DUD	(1248)

Entry points: SYSSY

Variables:

R*4	FM	R*4	G	R*4	GG	I*4	I
I*4	KJ	I*4	LJ	I*4	NN	R*4	P

Arrays:

R*4	FAM	(14, 12)
R*4	SYS	(9, 16)

Module: TARGET

```
CALL: SUBROUTINE TARGET(FREQQ,HANG,TYPE)

Call Arguments:
  FREQQ       operating frequency, mhz
  HANG        horizontal angle of the ray for type -3, degrees
  TYPE        positive is the target size in dbsm, negative is:
              -1.0 is an aircraft
              -2.0 is other #1
              -3.0 is other #2

 **  return value

Purpose:    Computes the target size in dB above 1 meter² .

Included Commons:                 Size (4 byte words)
 TTSIZE                             (       180)

Entry points: TARGET

Variables:
 R*4    ADEL        R*4    ANGLE       R*4    AZR         R*4    AZRD
 R*4    AZV         R*4    AZVD        R*4    COSRMA      R*4    DTOR
 R*4    ELL         R*4    ELR         R*4    ELRD        R*4    ELV
 R*4    ELVD        R*4    FDEL        R*4    FREQ        R*4    FREQQ
 R*4    HANG        I*4    IA          I*4    IAHI        I*4    IALO
 I*4    IFHI        I*4    IFLO        R*4    PI          R*4    RMA
 R*4    RTOD        R*4    SIZE        R*4    THIA        R*4    TLOA
 R*4    TMIN        R*4    TTAB        R*4    TYPE        R*4    XM
 R*4    XR          R*4    YM          R*4    YR          R*4    ZM
 R*4    ZR

Arrays:
 R*4  TAB1           (26, 4)
 R*4  TAB2           (26, 4)
 R*4  TABLE          (26, 8)
 R*4  TSIZE          (45)
 R*4  VMIN           (26)

Subroutines and Functions Referenced:
 R*4  MTH$ACOS        R*4  MTH$ALOG        R*4  MTH$AMOD        R*4  MTH$AS
```

Module: TAYLOR

CALL: SUBROUTINE TAYLOR (G,NG,F,NF,A)

Call Arguments:

```
 ** G     array of weights
  NG    dimension of G (15)
  F     workspace
  NF    dimension of F (5)
  A     base (1.4)

 **  return value
```

Purpose: calculate taylor series weights for ant09 subroutine.

Included Commons:
no user defined commons

Entry points: TAYLOR

Variables:

R*4	A	R*4	ANG	R*4	BN	R*4	D
R*4	GA	R*4	GN	I*4	I	I*4	M
I*4	N	I*4	NB	I*4	NF	I*4	NG
I*4	NO2	R*4	PI	R*4	RI	R*4	RM
R*4	RN	R*4	SIG2				

Arrays:

```
@ R*4  F          (*)
@ R*4  G          (*)
```

Subroutines and Functions Referenced:

R*4	MTH$ASIN	R*4	MTH$COS

Module: TIMVAR

CALL: SUBROUTINE TIMVAR

Purpose: Calculates time dependence of the numerical maps of ionospheric variables.

Included Commons:	Size (4 byte words)
All	(24)
DAT	(192)
GEOG	(340)
INP	(68)
ION	(436)

Entry points: TIMVAR

Variables:

R*4	ABI	R*4	AK	R*4	AZMTH	R*4	BK
R*4	C180	R*4	C360	R*4	CENLAT	R*4	CENLG
R*4	CK	R*4	CKC	R*4	CLOCK	R*4	COLO
R*4	CYCEN	R*4	DEBUG	R*4	DJR	R*4	DK

Arrays:

R*4	ABIY	(10)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	CLAT	(10)
R*4	CLCK	(10)
R*4	CLONG	(10)
R*4	F1C	(10)
R*4	F2C	(10)
R*4	FEC	(10)
R*4	FREL	(15)
R*4	GAMMA	(6)
R*4	GLAT	(10)
R*4	GY	(10)
R*4	HE	(10)
R*4	HF1	(10)
R*4	HF2	(10)
I*4	MONN	(13)
R*4	PSC	(4)
R*4	RAT	(10)
R*4	RD	(10)
R*4	SUN	(2, 12)
R*4	YME	(10)
R*4	YMF1	(10)
R*4	YMF2	(10)

Subroutines and Functions Referenced:

	EF1VAR	R*4	MTH$ACOS	R*4	MTH$COS	R*4	MTH$EX
R*4	YMAP						

Module: VERSY

CALL: SUBROUTINE VERSY (KIK,LIK,POLE,II,CLOCK)

Call Arguments:

KIK	start index for coefficient array
LIK	stop index for coefficient array
POLE	not used
II	sample area selected
CLOCK	array of local mean time at sample areas

** return value

Purpose: Calculates geographic variation of the numerically mapped ionospheric variables.

Included Commons:	Size (4 byte words)
All	(264)
DAT	(192)
GEOG	(388)
WMAPS	(1824)

Entry points: VERSY

Variables:

R*4	AK	R*4	BK	R*4	C180	R*4	C360
R*4	CENLAT	R*4	CENLG	R*4	CK	R*4	CKC
R*4	CLG	R*4	CLOCK	R*4	COND	R*4	CX
R*4	DK	R*4	EEK	R*4	EK	R*4	EPR
R*4	FJ	R*4	GLG	R*4	GLT	R*4	GOB
I*4	I	I*4	II	I*4	IO	I*4	J
I*4	JB	I*4	JG	I*4	K	I*4	KA
I*4	KDIF	I*4	KIK	I*4	KK	I*4	LIK
I*4	LO	R*4	PI2	R*4	POLE	R*4	RZ
R*4	SX	R*4	T	R*4	X	R*4	Y

Arrays:

R*4	AB	(76, 6)
R*4	ABIY	(10)
R*4	AMON	(12)

Subroutines and Functions Referenced:

R*4	MTH$COS	R*4	MTH$SIN

Module: VERTIM

CALL: SUBROUTINE VERTIM

Purpose: Calculates the time variation of ionospheric variables for sample areas.

Included Commons:	Size (4 byte words)
All	(264)
A3	(23712)
DAT	(192)
INP	(68)
WMAPS	(1824)

Entry points: VERTIM

Variables:

R*4	AK	R*4	AZMTH	R*4	BK	R*4	C180
R*4	C360	R*4	CK	R*4	DK	R*4	EEK
R*4	EK	R*4	GLG	R*4	GLT	R*4	GMT
I*4	I	I*4	ICCP	I*4	IEXD	I*4	IO
I*4	J	I*4	JB	I*4	K	I*4	KA
I*4	MAN	I*4	METH	I*4	METHOD	I*4	MONS
R*4	PI2	R*4	RZ	R*4	SSN	R*4	TIME
R*4	X1	R*4	Y1				

Arrays:

R*4	AB	(76, 6)
R*4	ALOOK	(6)
R*4	AMON	(12)
R*4	C	(8)
R*4	D	(13, 76, 6)
R*4	GAMMA	(6)
I*4	KQ	(6, 10)
R*4	S	(8)
R*4	SUN	(2, 12)

Subroutines and Functions Referenced:

R*4	MTH$COS	R*4	MTH$SIN

Module: VPLOT

```
CALL: SUBROUTINE VPLOT (JPT,L)

 Call Arguments:
   JPT       task flag
             JPT > 0 Printout vertical ionograms
             JPT = 0 Printout absorption loss factor vs. frequency
   L     sample area selector

  **   return value

 Purpose: Print vertical ionograms in fortran unit 30

 Included Commons:              Size (4 byte words)
  APLT                            (       20)
  A2                              (   432000)
  ES                              (      160)
  GEOG                            (      388)
  HGH                             (    28800)
  ION                             (      360)
  INP                             (       28)
  LUNITS                          (       48)

 Entry points: VPLOT

 Variables:
  R*4     AZMTH        I*4     BLANK        R*4     CKC          R*4     COND
  R*4     EPR          R*4     FREQ         R*4     HLOWER       R*4     HUPPER
  I*4     I            I*4     IAZMTH       I*4     IFREQ        I*4     IFX
  I*4     II           I*4     IK           I*4     IMONS        I*4     IR
  I*4     ISSN         I*4     IT           I*4     J3           I*4     JJ
  I*4     JPT          I*4     K            I*4     L            I*4     LANT
  I*4     LCON         I*4     LGEO         I*4     LI           I*4     LIONO
  I*4     LMAP         I*4     LNOISE       I*4     LOUT1        I*4     LOUT2
  I*4     LOUT3        I*4     LSCRT        I*4     LSEMI        I*4     LTAR
  I*4     NBLANK       I*4     NELAY        I*4     PLUS         I*4     STAR
  I*4     XMINUS

 Arrays:
  R*4   ABIY          (10)
  R*4   AFAC          (240, 10)
  I*4   B             (51)
  I*4   BB            (6)
  I*4   C             (51)
  R*4   CLAT          (10)
  R*4   CLCK          (10)
  R*4   CLONG         (10)
  R*4   DUMMY         (6)
  I*4   F             (240)
```

Module: XFR3

```
CALL: SUBROUTINE XFR3(ARG,R)

Call Arguments:
  ARG       array of 3 values:
            arg(1) colatitude of new pole in radians
            arg(2) east longitude of new pole in radians
            arg(3) azimuth wrt new pole of new prime meridian in radians
  R      computed rotation matrix element

 **  return value

Purpose:   Computes rotation matrix element

Included Commons:
 no user defined commons

Entry points: XFR3

Variables:
 I*4    I              R*4    R1             R*4    R2             R*4    R3
 R*4    R4

Arrays:
@ R*4   ARG            (3)
  R*4   C              (3)
@ R*4   R              (3, 3)
  R*4   S              (3)

Subroutines and Functions Referenced:
 R*4   MTH$COS              R*4   MTH$SIN
```

Module: XLIN

CALL: FUNCTION XLIN (Y,YN,K,DELX,NTAB,JK)

Call Arguments:

```
  Y      value to interpolate from YN
  YN     table of values to interpolate from
  K      index to second dimension of tabe YN
  DELX       increments in YN index variable
  NTAB       first dimension of YN
  JK     task flag
             JK = 1, interpolate for dependent variable (conventional linear
             interpolation)
             JK = 2+ look up independent variable from a known value of the
             dependent variable (conventional look-up)

 **   return value
```

Purpose: Perform linear interpolation on a table of values, or use the table of values to perform a look up (inverse interpolation).

Included Commons:
no user defined commons

Entry points: XLIN

Variables:

R*4	DELX	I*4	IS	I*4	ISMAX	I*4	ISMIN
I*4	IY	I*4	J	I*4	JK	I*4	K
I*4	NMIN1	I*4	NSRT	I*4	NTAB	R*4	XN
R*4	Y	R*4	YZ				

Arrays:

@ R*4 YN (1)

Module: YMAP

CALL: REAL FUNCTION YMAP (CLOCK, GMLAT, SSN, MONTH, DEBUG)

Call Arguments:

CLOCK	local mean time at a sample area
GMLAT	geomagnetic west latitude, degrees
SSN	running average sunspot number index of solar activity
MONTH	integer month
DEBUG	debug flag; debug output to fortran unit 34 generated for a value of 0

** return value

Purpose: Calculates the F2-layer semi-thickness from numerical coefficients

Included Commons:
LUNITS (48)

Entry points: YMAP

Variables:

R*4	CLOCK	R*4	DEBUG	R*4	GEOLAT	R*4	GMLAT
I*4	IC	I*4	IC1	I*4	IC2	I*4	IG
I*4	IG1	I*4	IG2	I*4	IOSTAT	I*4	ISUN
I*4	IX	I*4	IY	I*4	JMON	I*4	LANT
I*4	LCON	I*4	LGEO	I*4	LIONO	I*4	LMAP
I*4	LNOISE	I*4	LOUT1	I*4	LOUT2	I*4	LOUT3
I*4	LSCRT	I*4	LSEMI	I*4	LTAR	I*4	MONTH
L*4	READ	R*4	SSN	R*4	YM	R*4	YM11
R*4	YM12	R*4	YM21	R*4	YM22	R*4	YMAP1
R*4	YMAP2						

Arrays:
L*1 MAPBYT (0:24, 0:18

Subroutines and Functions Referenced:
FOR$CLOSE FOR$OPEN

Module: ZERO

CALL: SUBROUTINE ZERO

Purpose: Clears arrays which may contain data not wanted.

Included Commons:

ALLAMP	(10656)

Entry points: ZERO

Variables:

I*4	I	I*4	J	I*4	NBLANK

Arrays:

I*4	LAYSMB	(333, 4)
I*4	LAYSNR	(333, 4)

List of References

1.) Kelley, L. (1945), Calculation of skywave field intensities, maximum usable frequencies, U. S. Army Signal Corps Tech. Report No. 6.

2.) Central Radio Propagation Laboratory (1948), Ionospheric radio propagation, NBS Circular 462.

3.) Laitinen, P. 0., and G. W. Haydon (1950), Analysis and prediction of skywave field intensities in the high frequency band, U. S. Army Signal Radio Propagation Agency Tech. Report No. 9, Rev. (RPN 203).

4.) Stanford Research Institute (1957), The application of digital computing techniques to the problem of interference on HF communication circuits and networks, Special Report 1, SRI Project 2124, Menlo Park, California.

5.) Lucas, D. L., and G. W. Haydon (1961), MUF-.FOT predictions by electronic computers, NBS Report 6789. U. S. Department of Commerce, Boulder, Colorado.

6.) Lucas, D. L., and G. W. Haydon (1962), Predicting the performance of band 7 comnunications systems using electronic computer, NBS Report 7619.

7.) Headrick, J. M., and J. F. Thomason,et,al (1971) Virtual Path Tracing for HF Radar Including an Ionospheric Model, NRL Report 2226.

8.) Jones, W. B., and R. M. Gallet (1962), The representation of diurnal and geographic variations of ionospheric data by numerical methods, Radio Sci. (J. Res. fNB5), Nlo. 4, 419-438.

9.) Lloyd J. L., D. L. Lucas and G. W. Haydon, et,al, Techniques for Analyzing HF Systems, Unpublished notes.

10.) Leftin, M. (1976), Numerical representation of monthly median critical frequencies of the regular E region (foE), OT Report 76-88, Boulder, Colorado.

11.) Leftin, M., S. M. Ostrow, and C. Preston (1968), Numerical maps of foEs for solar cycle minimum and maximum, ESSA Technical Report ERL 73-ITS 63, Boulder, CO.

12.) Martyn, D. F. (1959), The normal F region of the ionosphere, Proc. IRE 47, No. 2, 147-155.

13.) Piggott, W. R., and K. Rawer (1961), URSI Handbook of ionogram interpretation and reduction (Elsevier Publishing Co., New York, New York). See also = Piggott and Rawer (1972).

14.) Shimazaki, T. (1955), Worldwide daily variations in the height of the maximum electron density of the ionospheric F2 layer, J. Radio Res. Labs., Japan, 2, No. 7, 86-97.

15.) Budden, K. G. (1966), Radio Waves in the Ionosphere (Cambridge University Press, Cambridge, England.

16.) Lucas, D. L., and G. W. Haydon (1966), Predicting statistical performance indexes for high frequency telecommunications systems, ESSA Tech. Report IER 1-ITSA 1,U.S. Department of Commerce, Boulder, Colorado 80303.

17.) Rosich, R. K., and W. B. Jones (1973), The numerical representation of the critical frequency of the F1 region of the ionosphere, OT Report 73-22, Boulder, Colorado.

18.) Haydon, G. W.,and D. L. Lucas (1968), Predicting ionosphere electron density profiles,Radio Science 3, ■-No. 13, pp. 111-119.

19.) Ratcliffe, J. A. (1951), A quick method for analyzing ionospheric records, J. Geophys. Res.56, 463-485.

20.) Jones, W. B., and F. G. Stewart (1970), A numerical method for global mapping of plasma frequency, Radio Sci. NNo. 5. 773-784.

21.) Croft, T. A. (1967i, HF radio focusing caused by the electron distribution between ionospheric layers, J. Geophys, Res., 72, No. 9, 2343-2355.

22.) Haselgrove, J. (1954), Ray theory and a new method for ray tracing, (Report of Conference on Physics of the Ionosphere, London Physical Society).

23.) Finney, J. B. (1963),Ray tracing development for propagation studies, NBS Report 7697.

24.) Lejay, P., and D. Lepechinsky (1950), Field intensity at the receiver as a function of distance, Nature 165, 306.

25.) Rawer, K. (ed.) (1976), Manual on Ionospheric Absorption Measurements, Report UAG-57, NOAA, Boulder, Colorado.

26.) CCIR (1970), CCIR interim method for estimating skywave field strength and transmission loss at frequencies between the approximate limits of 2 and 30 N1Hz,

CCIR Report 252-2, ITU, Geneva, Switzerland.

27.) Schultz, L. D., and R. M. Gallet (1970), A survey and analysis of normal ionospheric absorption measurements obtained from pulse reflections, ESSA Professional Paper 4.

28.) Barghausen, A. F., J. b!. Finney, L. L. Proctor, and L. D. 5chultz (1969), Predicting long-term operational parameters of high-frequency skywave telecommunication systems, ESSA Technical Report ERL 110-IT578, Washington, D. C., May.

29.) Piggott, W. R. (1953), The reflection and absorption of radio waves in the ionosphere, Proc. IEEE, Part III, No. 64, pp. 61-72.

30.) George, P. L. (1971), The calculation of ionospheric absorption in HF radio propagation prediction, WRE-Technical Note-A207(AP). Department of Supply, Weapons Research Establishment, South Australia

31.) Bibl, K., A. Paul, and K. Rawer (1961), Absorption in the D and E regions and its time variation, J. Atmospheric and Terrest. Phys. 23, 244-259, December.

32.) Fejer, J. A. (1961), The absorption of short.radio waves in the ionospheric D and E-regions, J. A.and T. P. 23, 260-274.

33.) Bremmer, H. (1949), Terrestrial Radio Waves (Elsevier Publishing Co., New York, New York).

34.) Wheeler, J. L. (1966), Transmission loss for ionospheric propagation above the standard MUF, Radio Science; 1, No. 11, 1303-1308.

35.) Philips, M. L. (1962), Evaluation of effective Es reflectivity of obscuration because of Es ionization, External Tech. N4emo No. 14, Electro-Physics Labs.

36.) Rice, P. L., A. G. Longley, K. A. Norton, and A. P. Barsis (1965), Transmission Loss Predictions for Tropospheric Communication Circuits, NBS Technical Note, No. 101, U.S. Department of Commerce, Boulder, Colorado.

37.) CCIR (1988) Characteristics and applications of atmospheric radio noise data, CCIR report 322-3, ITU Geneva.

38.) Elkins, T. J., (1980), A model for high frequency radar auroral clutter,RADC-TR-80-122.

39.) Elkins, T. J., (1991), A revised global OTH radar clutter model, MTR11219, Mitre Corp., Bedford,Mass.

40.) Headrick, J. M.,(1990), HF over-the-horizon radar, Chap 24 of the Radar Handbook edited by M. I. Skolnik, 2nd edition, Mc Graw Hill. New York.

41.) Wright J. W., L. R. Wescott, and D. J. Brown (1960-1963), Mean electron density variations of the quiet ionosphere, NBS Technical Notes 40-1 through 40-13, U. S. Department of Commerce, (U. S. Government Printing Office, Washington D. C.)